EXHIBIT B

CISCO SYSTEMS

Metro Edge Solution for Service Providers

Understanding Path Protected Mesh Networks (PPMN)

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Understanding Path Protected Mesh Networks (PPMN)

White Paper

Understanding Path-Protected Mesh Networks (PPMN)

Abstract

This document discusses a synchronous optical network/synchronous digital hierarchy (SONET/SDH) protection scheme for meshed networks. Examples in this document will use SONET, although path-protected mesh networks (PPMN) over SDH are also fully supported.

Meshed networks fall outside the common, Telecordia-specified protection schemes of bidirectional line-switched ring (BLSR) and unidirectional line-switched ring (UPSR). As a result, legacy SONET equipment manufacturers have not offered viable solutions for meshed networks. With PPMN capability, Cisco has extended the simple concept of path protection on a SONET ring to meshed networks, offering service providers a new degree of flexibility in designing their networks.

Introduction

In the past, most large carriers have focused their time division multiplexing (TDM) protection on ring architectures. no standards-based TDM protection solution currently exists, and as a result, legacy TDM equipment manufacturers have not offered viable solutions for meshed networks. At best, such solutions have been complex and proprietary. With PPMN, Cisco has extended the simple UPSR concept of ring-based path protection to meshed networks, offering service providers a new degree of flexibility in designing their networks.

With PPMN, a network planner can design a mesh that utilizes both protected and unprotected spans at various line rates. In the event of a failure on one route, connection is reestablished through another path in the mesh in less than 50 milliseconds (ms). This offers network planners flexibility they can use for mesh networks today.

By using path protection, PPMN simply extends UPSR beyond the basic ring topology to a meshed architecture. The software locates two diverse routes in the network between the source and destination. These two routes form a logical ring for that circuit's path and behave exactly as UPSR. The source bridges its traffic onto each of the diverse paths, and the destination selects between the two paths. A failure on the active path causes the destination to switch to the standby path within 50 ms. Because of its strict adherence to SONET standards, a PPMN logical ring is no different from the standard Telecordia-specified UPSR.

"Meshed networks" refers to any number of sites arbitrarily connected together with at least one loop. That is, each node has two or more links connected to it. In Layer 1 Transport architectures, TDM-based meshed networks are often large rings with a number of spurs or a series of rings that have become meshed over time, as shown in Figure 1.

Figure 1
Real-world TDM Meshed Networks

With PPMN, a network planner can design this mesh with unprotected spans and various line rates. In the event of a failure on one route, connection is reestablished through another path in the mesh within SONET's 50 ms restoration time.

Benefits of PPMN

PPMN gives network planners a great deal of flexibility, since the 50 ms restoration can be applied to networks other than rings. Also, because non-ring architectures can be used, it is possible to have protection over a series of unprotected spans. This means that if a network planner needs additional bandwidth, a single fiber pair can be pulled between sites, rather than building a whole new ring. This saves both time and money. In addition, it allows the planner to take advantage of pockets of unused spans throughout a network, increasing network utilization. As long as there are two paths between nodes, any span can be used for PPMN.

In addition to providing a network planner with added flexibility, Cisco's management system, the Cisco Transport Controller (CTC), makes provisioning within a meshed network as simple as clicking a mouse button, thanks to its Java-based GUI. All the nodes on the network begin the process of auto-discovery as soon as they are turned up. Within minutes, each node has a full description and status of the other nodes and connections throughout the network. This is possible because Cisco uses Internet Protocol (IP) and Open Shortest Path First (OSPF) protocols for data communications channel (DCC) communications.

Creating a circuit is then accomplished simply by specifying the source and destination—another Cisco innovation called A-Z Provisioning. Software determines the shortest path through the network and establishes all the intermediate cross connections. A check box determines whether the circuit is to be protected or not. When it is checked, PPMN is enabled: a protect circuit is established on the second shortest path through the network between the source and destination, and a second set of cross connections are created. With this capability, turn-up and provisioning of circuits can be done in a matter of minutes, rather than hours or days.

If necessary, the automatic route selections can be overridden and manual paths can be chosen. As with UPSR, the user is prompted for the following parameter settings:

- **Revertive**—Set for traffic to revert to the working path when the conditions that diverted it to the protect path are repaired.
- **Reversion time**—Set the reversion time. This is the amount of time that will elapse before the traffic reverts to the working path. Traffic can revert when conditions causing the switch are cleared.
- **SF threshold**—Set the UPSR path-level signal failure bit error rate (BER) thresholds.
- **SD threshold**—Set the UPSR path-level signal degrade BER thresholds.
- Switch on PDI-P—Set if traffic is to be switched when a path payload defect indicator is received.

PPMN Example

In Figure 2, a path needs to be set up between nodes A (left) and Z (right). The PPMN software will determine the shortest two routes between A and Z. Cross connections between A and Z will automatically be created over diverse routes. In the event of a fiber cut or other failure on the primary route, either node A or node Z will switch to the protection path, as shown here.

Figure 2
This needs a caption.]

Conclusion

Cisco's PPMN gives the service provider's network planner an added degree of flexibility and enables the service provider the ability to quickly turn up services utilizing PPMN and A-Z Provisioning. A-Z Provisioning enables the user to simply specify the beginning and ending points of a new circuit (shelf, slot, and port), and PPMN automatically selects an open path through the network, setting up the appropriate cross connections at intermediate nodes in the network. This reduces the time to deliver services and generate new revenues. By seamlessly integrating PPMN into the suite of protection schemes, Cisco has taken one more step in revolutionizing SONET/SDH transport.

EXHIBIT C

United States Patent

[15] **3,652,798**

McNeilly et al.

[45] **Mar. 28, 1972**

[54] **TELECOMMUNICATION SYSTEM**

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[73] Assignee: **International Standard Electric Corporation**, New York, N.Y.

[22] Filed: **June 8, 1970**

[21] Appl. No.: **44,396**

[30] **Foreign Application Priority Data**

July 28, 1969 Great Britain 37,764/69

[52] U.S. Cl. ....179/15 AL

[51] Int. Cl. H04j 3/00

[58] Field of Search ....179/15 AL, 175.31

[56] **References Cited**

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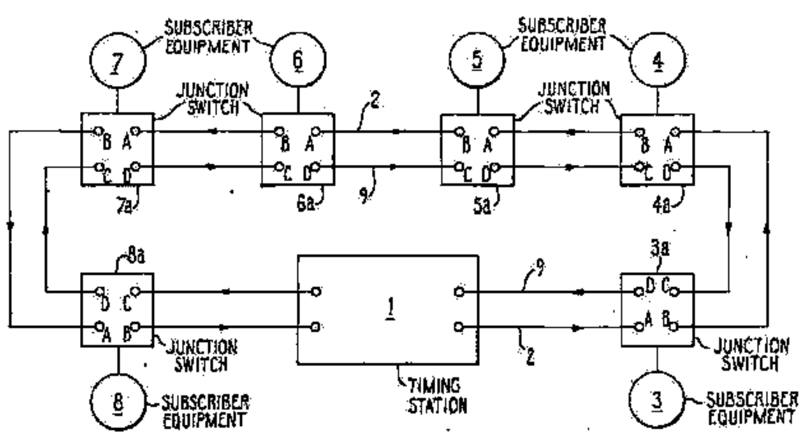
[57] **ABSTRACT**

A timing station provides time division multiplex channel signals on a first closed loop unidirectional transmission line interconnective in tandem subscriber stations, each of which may gain access to an unused channel signal for communication with an idle subscriber station. To protect against failure of the entire system due to a break in the line or failure in one of the subscriber stations, a second closed loop unidirectional transmission line is connected to all stations transmitting signals in a direction opposite to that on the first line. Each subscriber station can detect an error and transfer the communication signals on the first line to the second line. The subscriber station before the break transfers the communication signal to the second line and the subscriber station after the break transfers the communication signals back to the first line to form a new, but continuous closed loop. When communication signals are on the second line and a fault occurs, the transfer of communication signals will be similarly performed to provide still another new, but continuous closed loop by passing the fault. Two embodiments to detect a fault and control the transfer of communication between the two lines are disclosed.

9 Claims, 11 Drawing Figures



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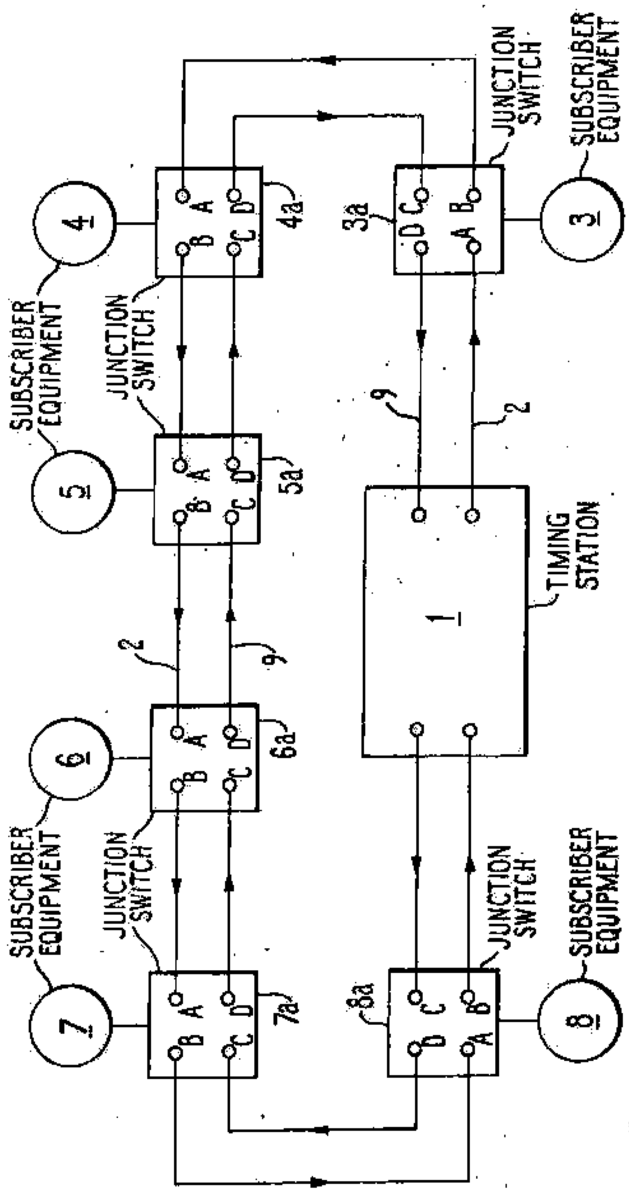

FIG. 1

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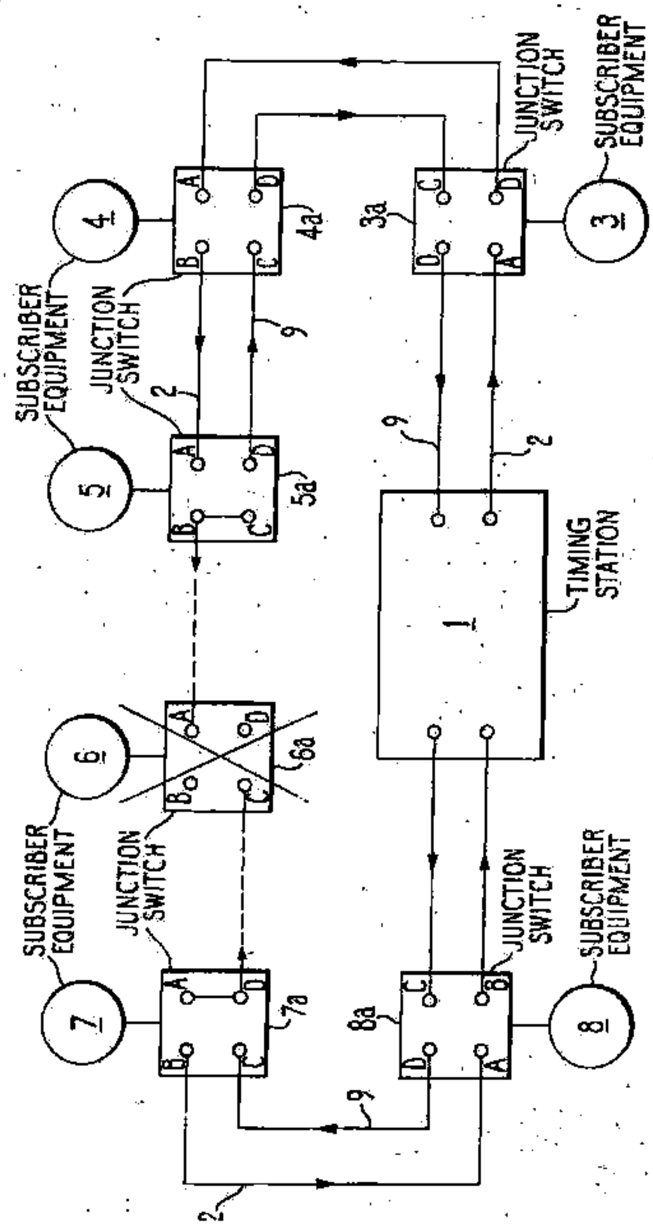

FIG.2

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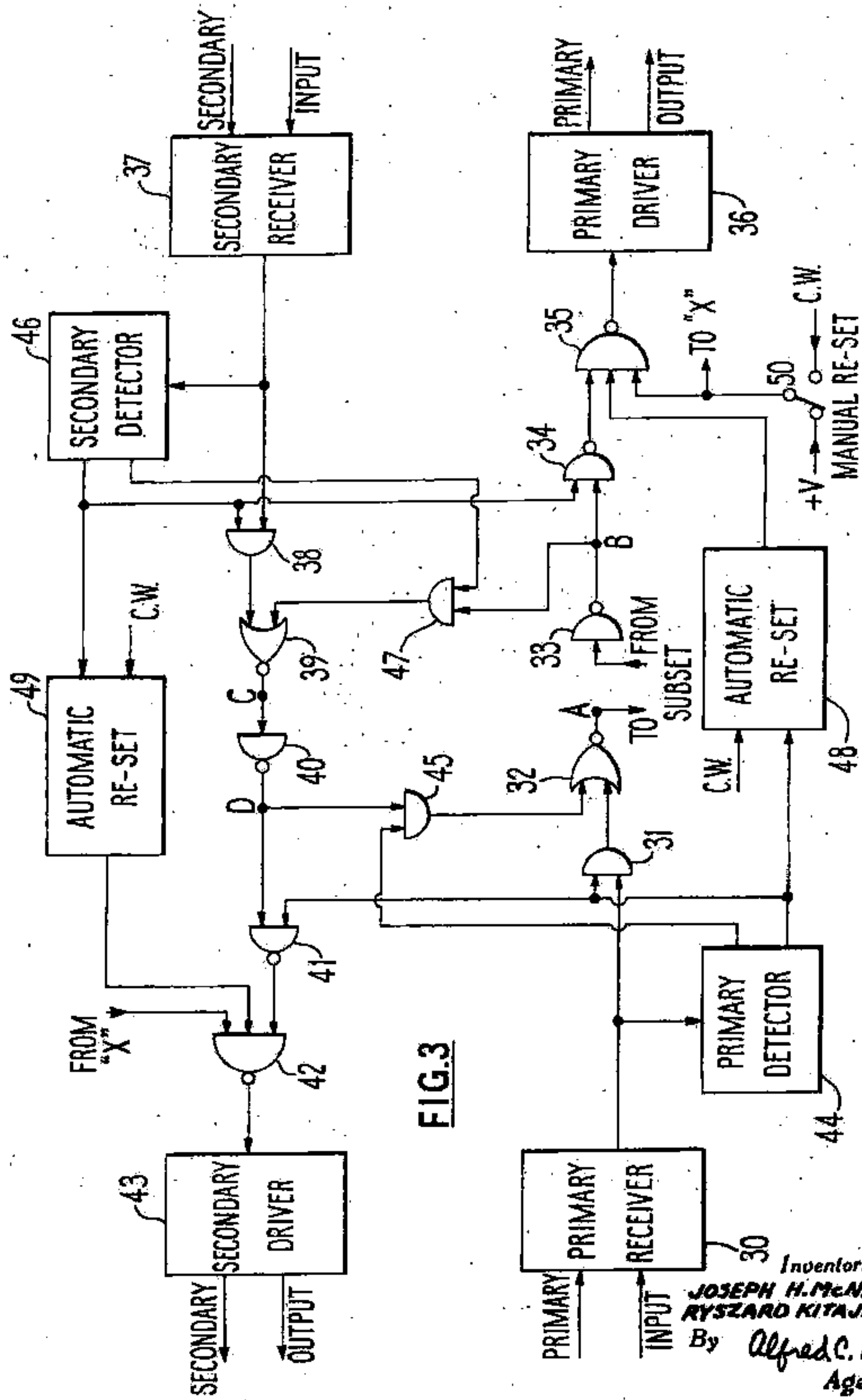

FIG.3

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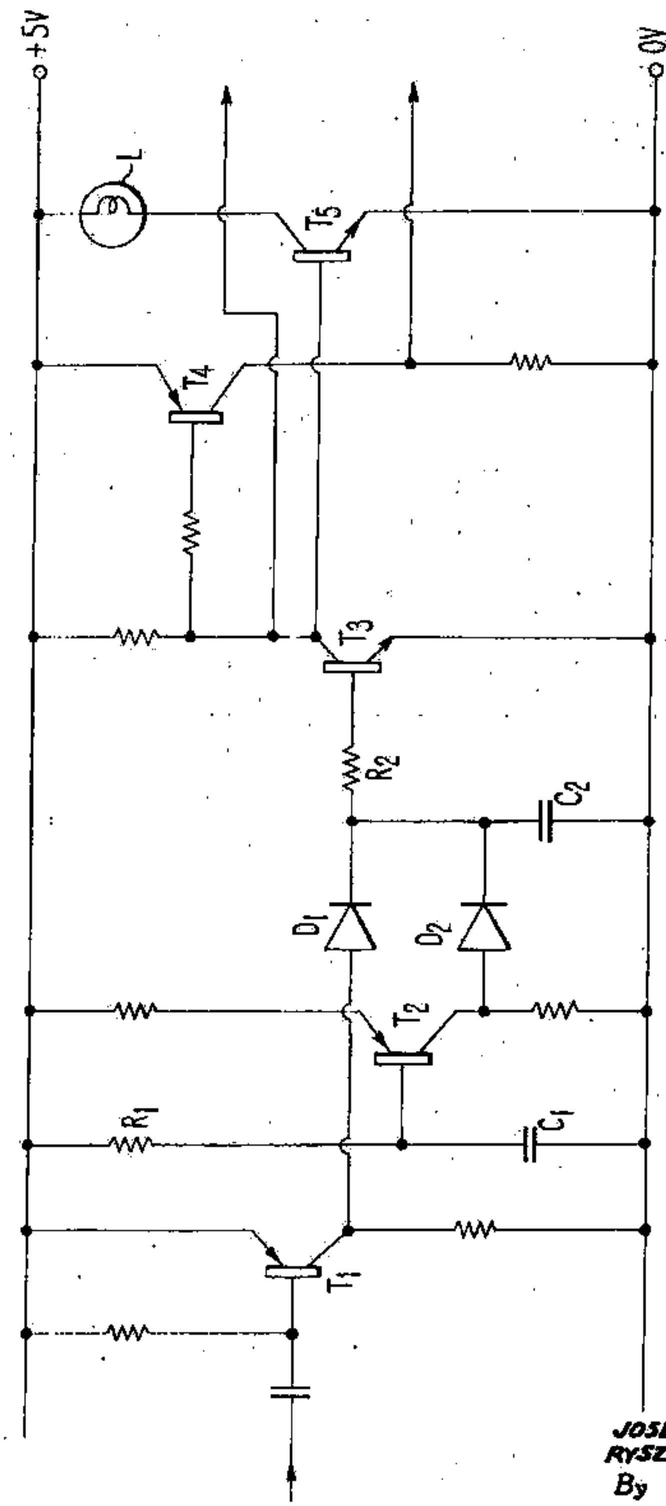

FIG.4

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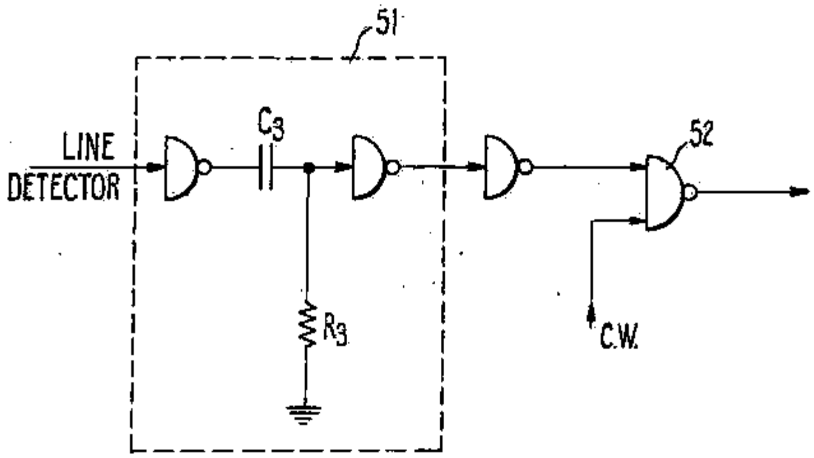

FIG. 5

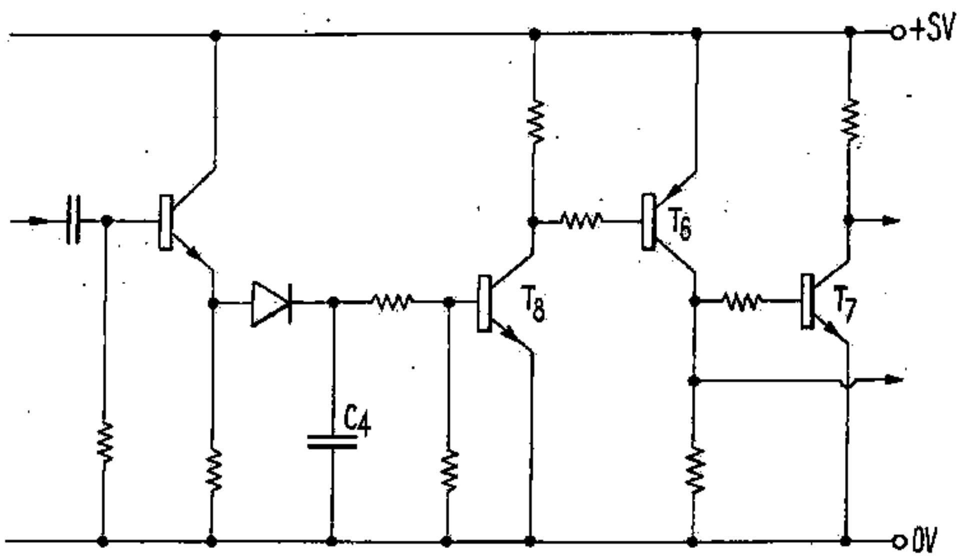

FIG. 8

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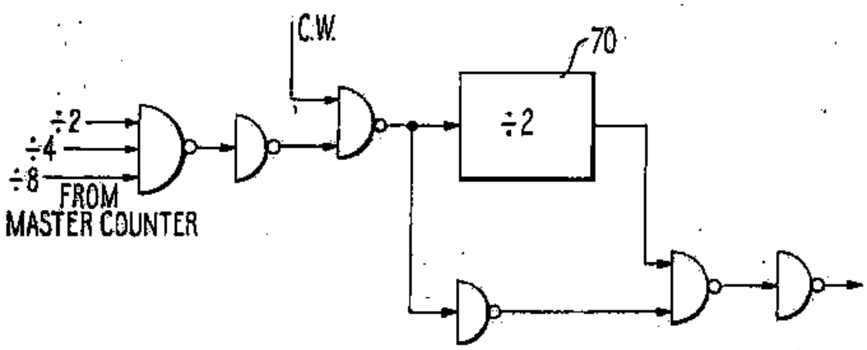

FIG.7

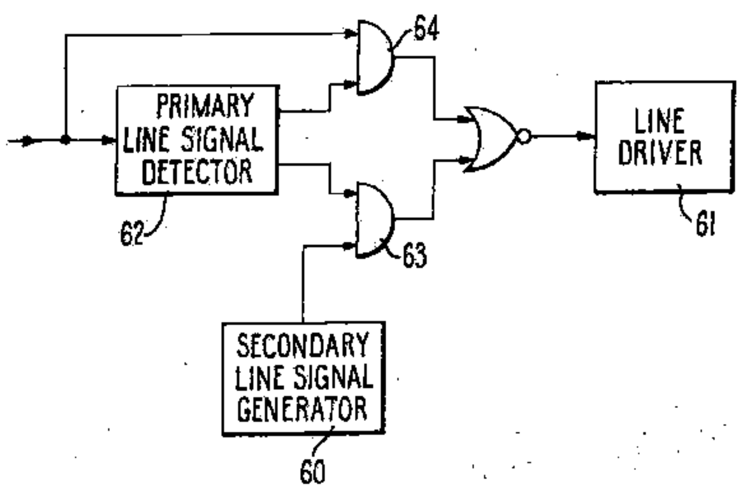

FIG.6

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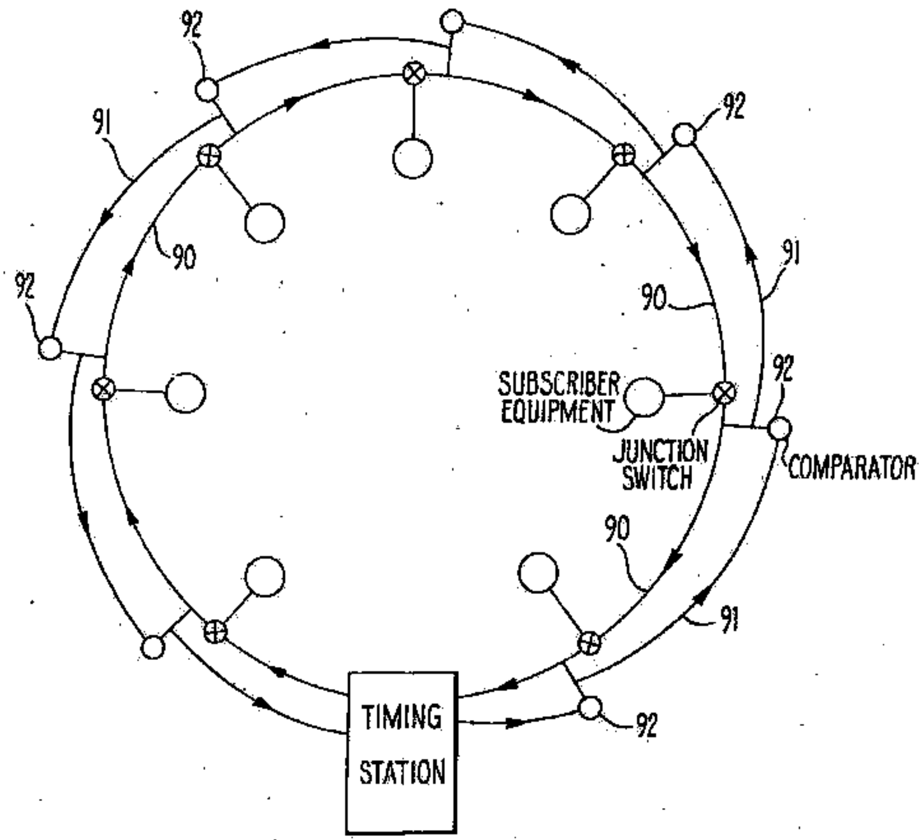

FIG.9

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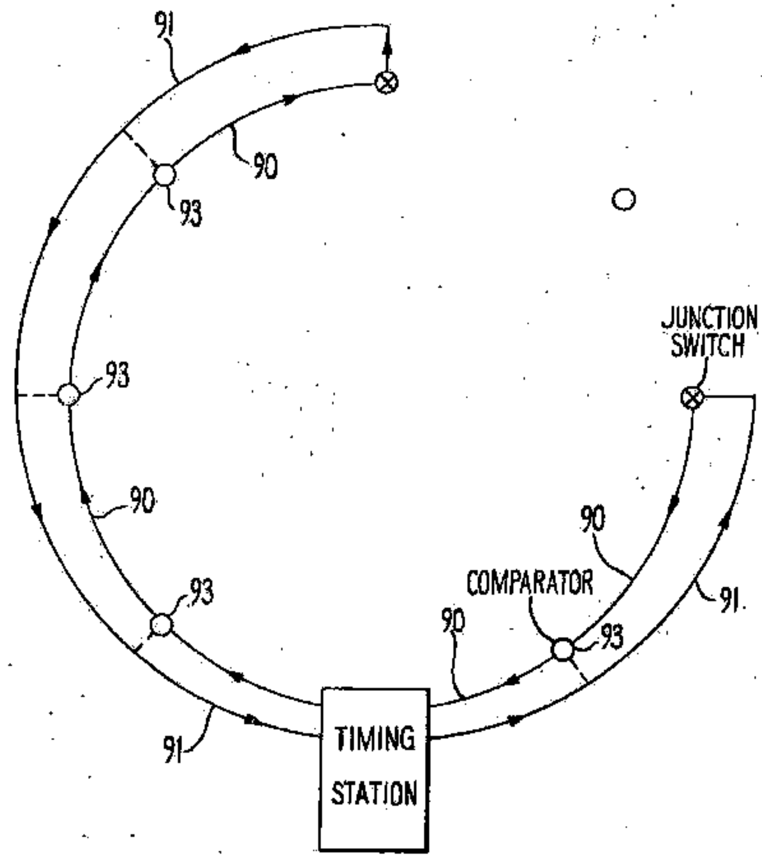

FIG. 10

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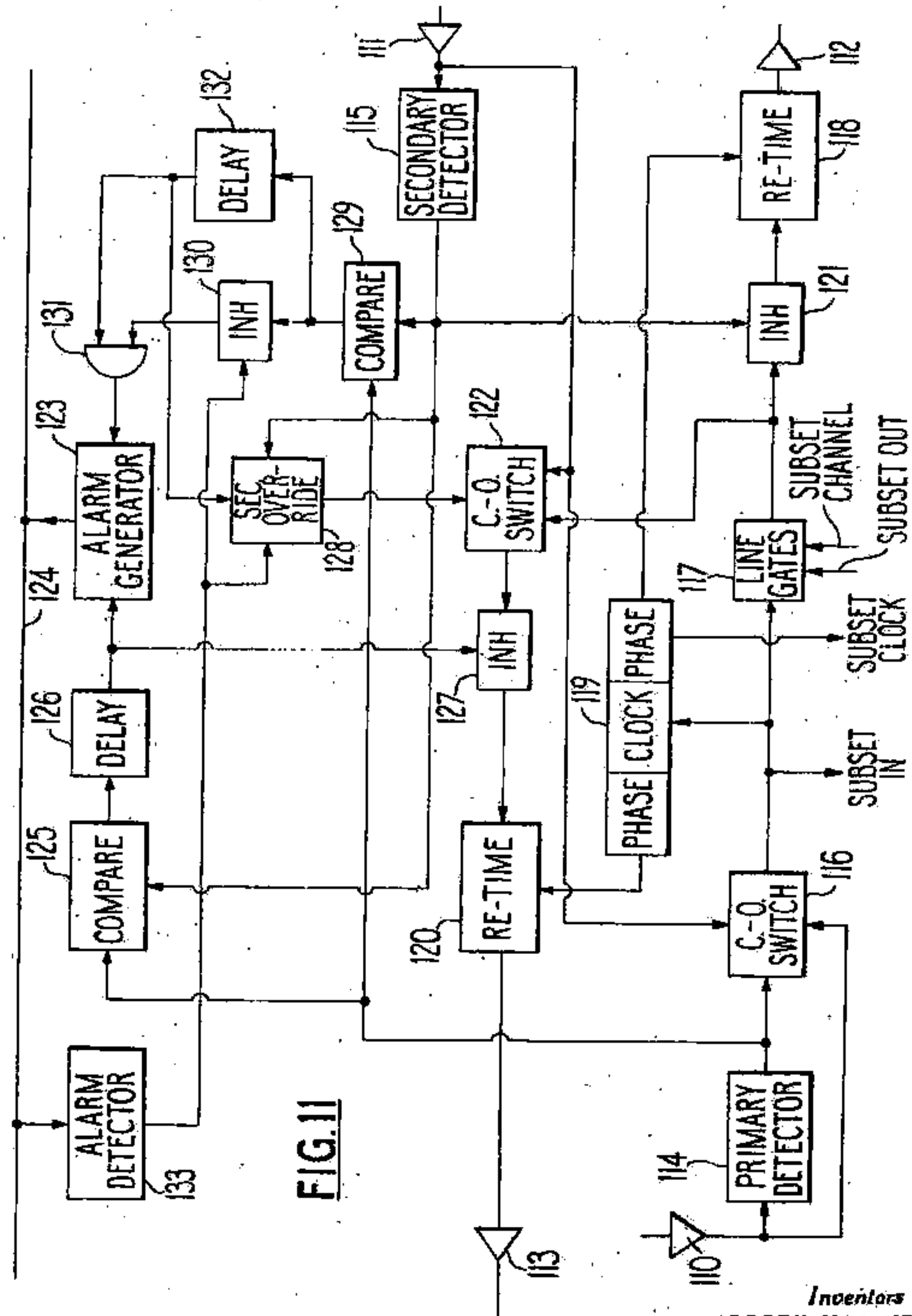

FIG. 11

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TELECOMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

This invention related to telecommunication systems, such as PCM (pulse code modulation) telephone networks, in which a group of subscribers have access to a common "ring main" loop line arranged for the continuous unidirectional circulation of time division multiplexed PCM signals.

Subscribers on the loop communicate with one another by seizing a free time slot in the loop by means of a line connecting means which connects the subscriber to the loop at the appropriate times. Signals from a first subscriber destined for a second subscriber are transmitted around the loop as far as the second subscriber and there terminated, while signals from the second subscriber for the first subscriber are transmitted around the remainder of the loop as far as the first subscriber and there terminated. If a subscriber is engaged in a call all other signals are merely regenerated and retimed and passed on to the next subscriber. The system makes use of subscriber equipment which incorporate individual pulse modulating and demodulating means, i.e., each subset includes a PCM coder and decoder. The advent of integrated solid state circuits enables such coder/decoders to be built into conventional sized telephone sets alongside other digital equipment, such as synchronizing, dialing and other circuits which can also be constructed in integrated circuits. This type of telecommunication system is fully described in the U.S. copending application of D.L. Thomas, Ser. No. 763,874, filed Sept. 30, 1968 having the same assignee as the present patent application.

A disadvantage of the system as outlined above is that if there is a break of fault in the system, i.e., a break in the ring main loop, then, since all signals have to pass round the loop, the system as a whole fails.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a telecommunication system of the type described above which overcomes the above-mentioned disadvantage of such systems.

Another object of the present invention is to provide an arrangement for a telecommunication system of the type described above to protect such a system against a failure in the loop thereof.

A feature of this invention is the provision of a telecommunication system comprising a first closed loop unidirectional transmission line for transmitting signals in one direction; a second closed loop unidirectional transmission line for transmitting signals in a direction opposite to the one direction; first means coupled to the first and second lines for providing on one of the first and second lines a plurality of time division multiplexed communication channel signals; and a plurality of subscriber stations coupled to the first and second lines, each of the stations including second means to connect that one of the stations to the one of the first and second lines to establish communication on an unused one of the channel signals with an idle one of the stations, third means for detecting a first fault in the one of the first and second lines, and fourth means coupled to the third means responsive to a detected first fault to interconnect the first and second lines and transferring the channel signals on the one of the first and second lines to the other of the first and second lines, thereby cooperating to provide a first new closed loop unidirectional transmission line to bypass the fault.

According to the present invention there is provided a telecommunication system including a plurality of subscriber stations, a first closed loop unidirectional transmission line to which each subscriber may be connected, means for providing on the looped line a number of time multiplexed communication channels, each subscriber having synchronizing means whereby that subscriber may be connected to any unused channel to make a connection to another subscriber not already engaged in an existing connection, a second unidirectional transmission line parallel to the first line to which each of the subscribers and the channel providing

means may be connected, each subscriber station having means for detecting a fault condition in the first line and means for terminating each line and transferring the signals from one line to the other line in the event of a fault being detected, the transferred signals being propagated in opposite directions round the two lines, means for generating an alarm signal indicating a fault condition, and means responsive to such an alarm signal to inhibit the terminating of the two lines in all subscriber stations except those initially detecting a fault condition.

Thus, if a fault occurs in the first loop, which is the one normally in use, at the station immediately preceding the fault the signals are transferred to the second loop and sent all the way back to the station immediately following the fault, where the signals are transferred back to the first loop. In other words, if the first loop is broken, a new loop approximately twice the length of first loop is created which still connects all the subscriber stations except the faulty one. If two or more faults occur, then that section of the system, between two faults, which contains the timing station remains in operation as a shortened double length loop.

The present invention is concerned only with avoiding faults which occur in the loop lines or the subscriber stations. For the purposes of this specification, it will be assumed that the timing station is operating correctly.

BRIEF DESCRIPTION OF THE DRAWING

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram of the basic structure of a PCM ring-main telephone system with two looped transmission lines in accordance with the principles of the present invention;

FIG. 2 is a block diagram of the system of FIG. 1 when a fault occurs in a subscriber station;

FIG. 3 is a block diagram of part of a subscriber station in the system of FIGS. 1 and 2;

FIG. 4 is a schematic diagram of the line fault detector used in the subscriber station of FIG. 3;

FIG. 5 is a schematic diagram of the automatic reset logic used in the subscriber station of FIG. 3;

FIG. 6 is a block diagram of additional circuitry used in the timing station of FIGS. 1 and 2;

FIG. 7 is a block diagram of a secondary line signal generator used in the timing station circuitry of FIG. 6;

FIG. 8 is a schematic diagram of a primary line signal detector used in the timing station circuitry of FIG. 6;

FIG. 9 is a block diagram of another embodiment of the basic system of FIG. 1;

FIG. 10 is a block diagram of the system of FIG. 9 when a fault occurs in a subscriber station; and

FIG. 11 is a block diagram of the circuitry of part of a subscriber station in the system of FIGS. 9 and 10.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the system shown in FIG. 1, the timing station 1 generates a synchronizing signal in one channel of a time division multiplex multichannel frame and empty-channel signals in all the other channels. These signals are transmitted unidirectionally around the closed loop unidirectional transmission line 2, hereinafter referred to as the "primary line." Each of the subscriber stations include subscriber equipment 3–8 and junction switches 3a–8a. Equipment 3–8 has access to line 2 and to the TDM channel signals thereon via its associated one of junction switches 3a–8a. All the primary line signals are fed into each subscriber station. A call from one subscriber to another is effected by the calling station identifying and locking on to an empty channel. The empty channel signal is replaced by a signal identifying the called subscriber. The latter recognizes its own unique signal on a hitherto empty channel and locks onto that channel. The called station modi-

fies the identity signal to indicate that it is ready to proceed with a call — this modified signal travels round the remainder of the primary line loop to the calling station which is then able to put PCM speech signals into the channel. If the called station is already engaged, the unmodified identity signal is allowed to proceed past the called station and when it is received back at the calling station the latter recognizes it as a busy signal.

It will be appreciated, therefore, that, in the absence of any special fault-avoidance arrangements, any fault which breaks the primary line would disable the entire system.

According to the present invention the system includes a secondary line 9 running parallel to the primary line. Signals on the secondary line travel in the opposite direction to those on the primary line. Under normal operating conditions, the secondary line carries a unique standby signal generated at timing station 1. Each subscriber station junction switch has facilities for distinguishing between the presence and absence of signals on either line. The system also includes facilities for generating alarm signals and each junction switch has means for detecting the presence of alarm signals generated by other junction switches.

The system to be described can deal with the following faults:

a. Both primary and secondary lines open circuit or short circuit;

b. Primary line open circuit or short circuit;

c. Secondary line open circuit or short circuit; and

d. Two or more of the above faults occurring simultaneously.

Consider the operation of the junction switches shown in FIG. 1. During normal operation each junction switch completes the primary line by virtue of a connection from A to B. The secondary line is completed at each switch by a connection from C to D.

Consider now the fault situation illustrated in FIG. 2, where a fault occurs in subscriber station 6 such that the system as a whole fails. Junction switch 7*a* detects the absence of signals on the primary line and diverts the output from D, which would have otherwise gone to 6*a*, to terminal A in 7*a*. At the same time it sends an alarm signal out over the primary line to junction switch 8*a*. Junction switch 8*a* detects initially the absence of signal on the primary line and operates to break the two lines and connect A to D as in the case of junction switch 7*a*. However, it is still able to receive the alarm signal from 7*a* and when this is received the A to D connection is broken and the switch reverts to normal operation. This procedure is repeated until the alarm signal reaches junction 5*a*, where it is transferred to the secondary line and so eventually reaches timing station 1 for the second time, having once passed through timing station 1 on the primary line. The timing station then removes from its outgoing secondary line 9 the unique standby signal and connects the outgoing line directly to a bypass connection in the timing station.

Timing station 1, therefore, incorporates three extra circuits for the purposes of the present invention, a standby signal generator, a primary line signal detector and a bypass switch.

Thus, after only a brief pause, all the subscriber stations except station 6 are again connected by a new unbroken closed loop line running through junction switches 3*a*, 4*a* and 5*a* on the primary line, returning through 4*a*, 3*a*, timing station 1, 8*a* and 7*a* on the secondary line and, thus, finally back to timing station 1 through 7*a* on the primary line.

Should a fault occur in one of the lines between two subscriber stations the same procedure occurs with respect to the station which detects the fault. Thus, if the primary line is broken or short circuited between stations 5 and 6, the transfer and alarm procedure is initiated by junction switch 6*a*. At the same time, secondary line 9 is interrupted by the transfer switching operation in junction switch 6*a* and junction switch 5*a* detects the loss of standby signal in secondary line 9 and initiates a transfer procedure as before. Again the system is restored to full operation — this time without the loss of a subscriber station.

If the fault between stations 5 and 6 was in the secondary line similar procedures would be followed, except that in this case junction switch 5*a* would be the first to respond.

If two or more faults occur simultaneously, the subscribers on either side of timing station 1, between timing station 1 and the nearest fault, will be provided with restricted service, but the subscribers between the faults will lose their service.

The main parts of a subscriber station junction switch relating to the present invention are illustrated in FIG. 3. The points A, B, C, D correspond to A, B, C, D in FIGS. 1 and 2.

In normal operation, the primary line input is connected to the primary line output via the primary line receiver 30, gates 31, 32, the speech and dialling portion of the subset, gates 33, 34 and 35, and the primary line driver 36. Similarly, the secondary line is completed through receiver 37, gates 38, 39, 40, 41, 42 and driver 43.

When a faulty condition occurs so that there is a loss of signal on the primary line input, this is detected by primary line detector 44. As a result of this gate 31 is disabled, gate 41 is disabled and gate 45 is enabled. The junction switch is, thus, isolated from the primary and secondary lines on the fault side of the switch and the signals appearing at D on the secondary line are transferred to A on the primary line via gate 45.

Should the fault be on the secondary line, secondary line detector 46 operates in exactly the same manner the signals at point B are transferred via gate 47 to point A.

The function of line detectors 44 and 46 is to detect the absence of a line signal. This is achieved in the circuit shown in FIG. 4. A return-to-zero, 50 percent duty cycle, line signal is used. The line signal, after amplification and inversion in transistor T_1 is passed on through diode D_1 to be integrated and stored on capacitor C_2. Provided that the potential across capacitor C_2 is greater than V_{BE} (base to emitter voltage) of transistor T_3, transistors T_3 and T_4 will conduct with their collectors approximately at 0 and + 5 volts, respectively. These are the potentials required for the junction switch to pass the line signal through. When line signal disappears, capacitor C_2 loses its charge through resistor R_2 and base-to-emitter resistance R_{BE} of transistor T_3 (neglecting other factors) until the potential across capacitor C_2 drops below the V_{BE} junction potential of transistor T_3. Transistors T_3 and T_4 will then be nonconductive with the collectors approximately at + 5 volts and 0 volts, respectively. The potentials from the line detectors are now reversed causing the junction switch to divert the line signal from one closed loop line onto the other closed loop line in response to a fault.

Resistor R_1, capacitor C_1, transistor T_2 and diode D_2 form a circuit that prevents the system from locking itself into the shortest loop at the instant of switching on the power supply, i.e., at the instant of switching the power supply on capacitor C_1 presents a short circuit to base collector junction of transistor T_2, making transistor T_2 conductive, thus, causing capacitor C_2 to be charged through D_2. The potential across capacitor C_1 rises with a time constant C_1 R_1 towards the supply voltage. When the potential across resistor R_1 falls below the potential of the base-emitter junction of transistor T_2, transistor T_2 stops conducting, and the charge on capacitor C_2 leaks away in a normal way through R_2 and the base-emitter resistance of transistor T_3. The time constant C_2 R_2 T_3 (R_{BE}) is sufficiently long ($\approx$100 μsec.) to keep the junction switches conductive until both primary and secondary lines complete the longest new closed loop ring.

Transistor T_5 is used to monitor the presence of a line signal on the ring. Normally, transistor T_5 is non-conductive with the monitor (lamp L) off. When the line signal disappears, transistor T_5 conducts, bringing the monitor on, thus, indicating a fault.

When a fault occurs each junction switch in turn would detect the absence of signal. The system would, therefore, tend to lock itself onto the shortest loop around the timing station. To prevent this happening an automatic reset (48, 49 FIG. 3) is included. This comprises a monostable 51 and an output gate 52 (FIG. 5). The input to the automatic reset is derived from the line detector. When a signal disappears, the outputs

of a line detector change state causing the monostable to produce an output pulse. The pulse width is determined by the time constant of capacitor C_3 and resistor R_3 in FIG. 5, e.g. approximately 100μsec. For the duration of this pulse, a simulated line signal (C.W.) will be sent to the proceeding junction switch commanding it to hold the junction switch ready to receive the true line signal. As explained previously, all the junction switches to the left and to the right of the fault will receive the automatic alarm signal, except the two nearest the fault. These two will remain in the new state, i.e., transferring the signal from one line to the other. Thus, due to automatic reset the longest loop round the ring has been established. In the case of multiple faults, the subscribers on each side of timing station 1, between station 1 and the faults will form a new loop, those between the faults will lose service.

The junction switch shown in FIG. 3 also includes manual reset arrangements to bring the faulty section into the circuit after it has been repaired or replaced. A push button 50 is depressed and substitutes a C.W. signal for the DC supply to gate 35 and, via the connection X — X, to gate 42. The appearance of this C.W. signal on the primary and secondary lines at the adjacent junction switches is detected by the appropriate line detectors and makes them conducting, ready to receive the line signals. When the push button is released the line signals keep the line detectors in the conducting condition, the transfer connections are broken and the line signals are re-routed through the re-connected section.

FIG. 6 shows the additional circuitry required in timing station 1, said copending application disclosing the remaining equipment of station 1. The secondary line signal generator 60 is used to generate the unique or standby signal applied to the secondary line driver circuit 61. When a fault occurs this signal is replaced at some point in the system by the re-routed primary line signals. The primary line signal detector 62 detects the loss of the standby signal and disconnects the signal generator 60 from the driver circuit 61 by closing gate 63.

At the same time it completes the loop by energizing gate 64 creating a direct link between the secondary line input and output.

The secondary line signal generator is shown in more detail in FIG. 7. Basically a train of pulses (i.e., the empty channel pulses) from the timing station master counter is gated with the C.W. signal and divided by two in the divider circuit 70. The divider output is gated with the input and the resultant pulse train is applied to the secondary line driver circuit. This signal has a pulse repetition rate half that of the primary line signals.

The primary line signal detector 62 is shown in detail in FIG. 8. The function of the detector is to distinguish between the primary and secondary line signals on the secondary line input to the timing station. Normally, when a secondary signal is being received, the transistors T_6 and T_7 are nonconductive, keeping their collectors at 0 and +5 volts, respectively. Now, if a primary line signal appears on the secondary ring or line, and because its p.r.f. is at least twice the secondary line signal, the charge in C_4 increases sufficiently to bring transistor T_5 into conduction, causing transistors T_6 and T_7 to conduct, thus, changing their collector potential to +5.0 and 0 volts respectively. This change of state in transistors T_6 and T_7 collectors activates a changeover switch in timing station 1. Thus, the transmission of the secondary line signal ceases, and the primary signal will be transmitted instead. Now the primary signal leaves timing station 1 on the secondary line and returns to the timing station on the primary line, thus, completing the second half of the new loop.

FIG. 9 is a block diagram of another embodiment of the system of this invention. In this embodiment, the output to primary line 90 at each station is also sent back along secondary line 91 to the previous station. Each station has a comparator 92 by which it compares its own output with that of the next station along primary line 90. The degree of comparison may only be sufficient to establish that both stations are producing a digital output, or it may be precise enough to establish a high degree of correlation between the two signals.

If a signal is present at the output to a station on the primary line and no signal is received back on the secondary line, then a fault condition exists at the next station, or on the line between the two. This causes the mode of operation to change as shown in FIG. 10. At the station where the fault is detected a special alarm signal is generated, preferably out-of band and carried on a separate wire (not shown), and this signal is sent back through all the stations on the line including the timing station. The station which generates the fault signal continues to send back its own output and stops transmitting it in the forward direction, but all other stations on receipt of the alarm signal no longer send back their own output, but instead retransmit the signal coming in on the secondary line. Thus, the secondary line is made continuous from the station which first detects a fault back to the timing station and beyond. After passing through the timing station, the secondary line is still carrying a signal identical to the output from the station which detected the fault, and, because of the fault, there is no signal on the primary line.

To find the best point for feeding the secondary line back onto the primary, it is necessary to introduce another set of comparators 93. The first set compared the output from a station on the primary with the input on the secondary. The second set must compare the input to the station on the primary with the output on the secondary. This second set should be able to set and reset automatically depending on the inputs. If no signal is coming in on the primary line, then the signal on the secondary is injected, however, if later on a signal does appear on the primary, then it will have priority and will be relayed through the station in the normal way.

When a break occurs there will be no signal on the primary beyond the break. Each of the second group of comparators 93 on this section of the ring will register the absence of the primary and cause the signal on the secondary to be fed onto the primary. Since the comparators are reversible, they will all switch back again except the one closest to where the break occurred, thus, providing the closed loop of FIG. 10. If, after a few frames delay, a comparator of the second set is still causing the secondary signal to be fed onto the primary, then that station will also initiate the alarm. It will then continue feeding the secondary ring back onto the primary, but will stop transmitting the secondary signal to the next station. In this way the operating alarm circuits are duplicated so that even with the failure of one alarm, the change-over in operating conditions can still be carried out. Once an alarm has been set and the signal is being sent back along the other line, then inhibiting the further forward transmission into the damaged section ensures that intermittent faults are treated as permanent breaks. A station generating the alarm signal can only be reset manually.

The first set of comparators cause the system to switch between the two modes of operation: either sending back their own output on the secondary line or, in the presence of the alarm, relaying the signal coming in on the secondary. If the alarm is removed, or if the signal on the secondary line disappears due to a second fault developing, then the comparators revert to sending back their own output and continue to do so for a number of frames. This should restore the secondary input to all but the one closest to the fault. Either the alarm signal is still present, in which case all stations, except the one registering the new fault, switch back to acting as relays on the secondary or, if the original alarm signal has been removed by the fault, they will not switch back until the station registering the new fault has begun to generate and transmit the fault alarm signal. A station can only initiate the alarm signal after having transmitted its own output for a number of frames, and not if the secondary line signal disappears while it is acting as a relay on the secondary. In this way the second fault is located and the loop reconnected to include the maximum possible number of subscribers. Only the section between the two faults is excluded from service. The same process operates for a greater number of faults.

If the second fault occurs on the timing station primary output, then for half of the system of FIG. 10 the primary line

signal disappears. This is corrected as before: if no signal is coming in on the primary line then the signal on the secondary is injected. However, if later on a signal does appear on the primary then it will have priority and will be relayed through the subset in the normal way.

The constructional details of a subscriber station for the system shown in FIGS. 9 and 10 will now be described with reference to FIG. 11. The primary and secondary line inputs are terminated by their respective line receivers 110, 111. The outgoing signals are fed to the lines by the primary and secondary line drivers 112, 113. The primary and secondary line detectors 114, 115 detect the presence or absence of line signals on the incoming lines.

If the primary signals are present they are allowed through the switch 116 to the subset line gates 117 and on to the retiming circuit 118 and primary line driver 112. The signals passed to the line gates 117 are used to drive the local clock circuit 119 which includes phase selectors which control the retiming circuits 118, 120. The outputs of the two detectors 114 and 115 are the signals which are used for comparison purposes as outlined above. In this context "comparison" merely means "are both signals present or is one absent?"

It must be remembered that when a fault occurs, in either the primary or the secondary, two stations will detect the fault condition, one on either side of the fault. In both cases an alarm signal is generated by the alarm circuit 123 and sent out over the alarm wire 124. Three sets of circumstances will now be considered:

a. Failure in the primary line input;
b. Failure in the secondary line input; and
c. Receipt of an alarm signal on the alarm wire.

a. A fault occurs in the primary line between the station under consideration and the preceding station, i.e., the absence of a primary signal is detected by the detector 114. In terms of FIG. 11, the station concerned is the one to the right of the fault and this station is required to transfer the incoming secondary signal to the primary line where it forms the input to the subset and is then fed to the primary line driver. Therefore, detector 114 operates change-over switch 116 and the secondary signal replaces the primary signal at this point. At the same time comparator 125 generates an output if the secondary signal is present and the primary signal is absent. This output, after being delayed for a short time, typically two or three frames, by delay 126, operates the alarm generator 123 which puts out an alarm signal to the rest of the system over the alarm wire 124. The delayed output also operates an inhibit gate 127 which cuts off the secondary line output. Thus, the incoming secondary signals are rerouted onto the outgoing primary line.

b. A fault occurs causing the absence of the secondary line signals. This may be due to a fault in the secondary line from the succeeding station to the right, or a fault in the primary line leading to the station on the right. (It has been explained in the preceding example how the secondary signals may be cut off by the operation of gate 127.)

The secondary line detector 115 operates the inhibiting gate 121 and cuts off the primary output. No change-over of signals is required at changeover switch 122 because under normal conditions it is already passing the primary signals back along the secondary line. Comparator 129 delivers an output when the secondary is absent and the primary is present, and this operates the alarm circuit via the inhibit gate 130 and the OR gate 131. Since the alarm will be picked up immediately by the stations own alarm detector 133 which, for reasons to be explained later, is the control for the inhibit gate 130, a bypass for this gate is provided via the delay circuit 132. The alarm detector also controls gate 128 the function of which is explained below.

c. When no fault is detected by the station under consideration, but a fault is detected by another station, an alarm signal is detected by the alarm detector 133. The station is required to remove the primary signal which up till now has been returned on the secondary line to the preceding station and to replace it with the secondary line input.

The receipt of an alarm signal coupled with the presence of the secondary signal, as detected by detector 115, allows the output of delay 132 to pass through gate 128 and operate the changeover switch 122. This replaces the outgoing primary signals on the secondary line with the incoming secondary signals.

Suppose now that a second fault occurs which is detected at the station under consideration. The second fault can be either a failure of the primary input, or a failure of the secondary input. If the secondary input disappears, the relevant output of detector 115 overrides the existing alarm signal at gate 128 and removes the control from changeover switch 128. This restores the primary signal to the outgoing secondary line and the operating procedures are otherwise as described in (b) above. If the primary signal fails, the output of detector 114 inhibits the input to delay 132 by operating comparator 129. This also removes the control from gate 128 and the remaining procedures are as described in (a) above.

It will be noted that once a station has responded to an alarm generated elsewhere it will not be affected by further simultaneous alarms from other stations. Any alarm will be maintained so long as a fault condition remains.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

We claim:

1. A telecommunication system comprising:
a first closed loop unidirectional transmission line for transmitting signals in one direction;
a second closed loop unidirectional transmission line for transmitting signals in a direction opposite to said one direction;
first means coupled to said first and second lines for providing on one of said first and second lines a plurality of time division multiplexed communication channel signals; and
a plurality of subscriber stations coupled to said first and second lines, each of said stations including
second means to connect that one of said stations to said one of said first and second lines to establish communication on an unused one of said channel signals with an idle one of said stations,
third means for detecting a first fault in said one of said first and second lines, and
fourth means coupled to said third means responsive to a detected first fault to interconnect said first and second lines and transfer said channel signals on said one of said first and second lines to the other of said first and second lines, said first and second lines thereby cooperating to provide a first new closed loop unidirectional transmission line to bypass said first fault;
each of said stations further including
fifth means coupled to said third means for generating a first alarm signal upon detection of said first fault for transmission on said one of said first and second lines; and
sixth means responsive to said first alarm signal to inhibit said interconnection of said first and second lines in all of said stations except those of said stations initially detecting said first fault.

2. A system according to claim 1, wherein
each of said stations further include
seventh means for detecting a second fault in said other of said first and second lines; and
eighth means coupled to said seventh means responsive to a detected second fault to interconnect said first and second lines and transfer said channel signals on said other of said first and second lines to said one of said first and second lines, said first and second lines

thereby cooperating to provide a second new closed loop unidirectional transmission line to bypass said second fault.

3. A system according to claim 2, wherein each of said stations further include

ninth means coupled to said seventh means for generating a second alarm signal upon detection of said second fault for transmission on said other of said first and second lines, and

tenth means responsive to said second alarm signal to inhibit said interconnection of said first and second lines in all of said stations except those of said stations initially detecting said second fault.

4. A system according to claim 3, wherein each of said third means and seventh means includes

eleventh means for generating two different signals having a predetermined relationship in the absence of any fault,

twelfth means coupled to the associated one of said first and second lines for integrating and storing signals received from said associated one of said first and second lines,

a first source of reference signal having a given amplitude value,

thirteenth means coupled to said first source and said 12th means for comparing the amplitude value of said stored signal with said given value of said reference signal, and

fourteenth means coupled to said 13th means responsive to a predetermined change between said value of said stored signal and said given value of said reference signal to reverse said predetermined relationship of said two different signals.

5. A system according to claim 4, wherein said first means further includes

fifteenth means coupled to said other of said first and second lines to transmit a unique signal thereover; and each of said stations further includes

a second source of signal simulating said unique signal,

a monostable device coupled to said eleventh means responsive to one of said two different signals having a predetermined condition to produce an output pulse of predetermined width, and

gated means coupled to said second source, said monostable device and said associated one of said first and second lines responsive to said output pulse to couple said simulated unique signal to said associated one of said first and second lines for a duration equal to said predetermined width.

6. A system according to claim 5, wherein said first means further includes

sixteenth means coupled to said other of said first and second lines for detecting thereon signals normally appearing on said one of said first and second lines and producing a control signal under this condition; and

seventeenth means coupled to said 16th means and said 15th means responsive to said control signal to inhibit the transmission of said unique signal and to connect said other of said first and second lines coming into said first means directly to said other of said first and second line leaving said first means as long as said control signal is present.

7. A telecommunication system comprising:

a first closed loop unidirectional transmission line for transmitting signals in one direction;

a second closed loop unidirectional transmission line for transmitting signals in a direction opposite to said one direction;

first means coupled to said first and second lines for providing on one of said first and second lines a plurality of time division multiplexed communication channel signals; and

a plurality of subscriber stations coupled to said first and second lines, each of said stations including

second means to connect that one of said stations to said one of said first and second lines to establish communication on an unused one of said channel signals with an idle one of said stations,

third means for detecting a first fault in said one of said first and second lines, and

fourth means coupled to said third means responsive to a detected first fault to interconnect said first and second lines and transfer said channel signals to said one of said first and second lines to the other of said first and second lines, said first and second lines thereby cooperating to provide a first new closed loop unidirectional transmission line to bypass said first fault;

each of said stations transmitting over said other of said first and second lines the signals also transmitted over said one of said first and second lines; and

each of said stations further including

fifth means coupled to said first and second lines for comparing the signals received over said one of said first and second lines from the next preceding one of said stations with the signals received over said other of said first and second lines from the next succeeding one of said stations,

sixth means coupled to said fifth means for detecting a first predetermined degree of discrepancy between the compared signals,

seventh means coupled to said sixth means for generating an alarm signal in response to the detection of said first discrepancy,

eighth means responsive to an alarm signal generated by another one of said stations to inhibit the transmission of signals over said other of said first and second lines and to connect the incoming said other of said first and second lines to the outgoing said other of said first and second lines,

ninth means coupled to said sixth means responsive to the detection of said first discrepancy to inhibit the transmission of signals over said one of said first and second lines,

tenth means coupled to said first and second lines for comparing the signals received over said one of said first and second lines with the signals received over said other of said first and second lines,

eleventh means coupled to said 10th means for detecting a second different predetermined degree of discrepancy between the signals compared in said 10th means; and

twelfth means coupled to said 11th means responsive to the detection of said second discrepancy to transfer signals received over said other of said first and second lines to said one of said first and second lines, said 12th means being inhibited when said second discrepancy is no longer detected.

8. A system according to claim 7, wherein each of said stations further includes

thirteenth means coupled to said 11th means responsive to the detection of said second discrepancy for generating an alarm signal.

9. A system according to claim 8, wherein each of said thirteenth means includes

fourteenth means coupled to said eleventh means for inhibiting the generation of said alarm signal for a given period of time after the detection of said second discrepancy.

* * * * *

EXHIBIT D

United States Patent [19]

Sweeton

[11] **Patent Number: 4,527,270**

[45] **Date of Patent: Jul. 2, 1985**

[54] **COMMUNICATIONS NETWORK WITH STATIONS THAT DETECT AND AUTOMATICALLY BYPASS FAULTS**

[75] Inventor: **David C. Sweeton**, Cleveland Heights, Ohio

[73] Assignee: **Allen-Bradley Company**, Milwaukee, Wis.

[21] Appl. No.: **491,550**

[22] Filed: **May 4, 1983**

[51] **Int. Cl.**[3] **G06F 11/20; H04Q 9/00**

[52] **U.S. Cl.** **371/11**; 371/7; 370/16; 370/88

[58] **Field of Search** 371/7-9, 371/11; 370/16, 86, 88

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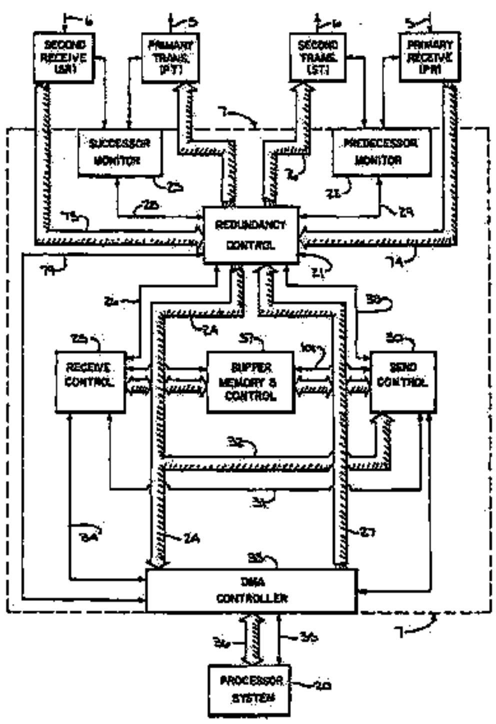
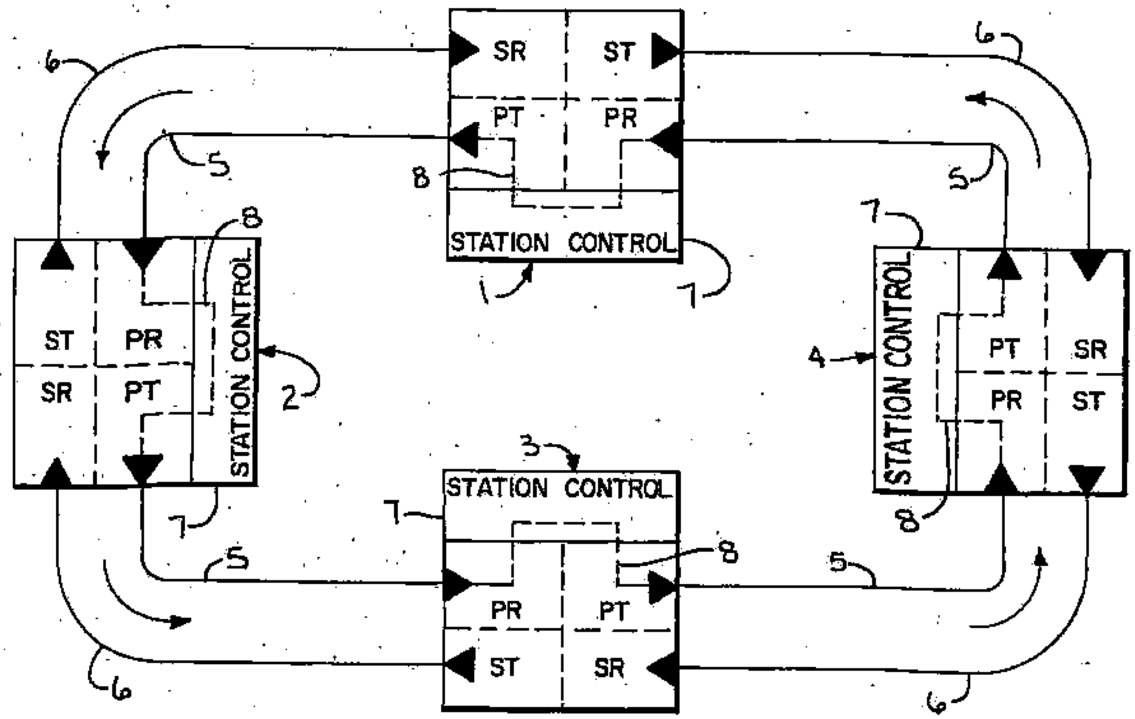
Primary Examiner—Jerry Smith
Assistant Examiner—Gary V. Harkcom
Attorney, Agent, or Firm—Barry E. Sammons

[57] **ABSTRACT**

A communication network suitable for industrial environments includes a set of stations which are linked together by a primary ring which conveys data in one direction around the ring and a secondary ring which conveys data in the other direction. The integrity of both the primary and secondary rings is continuously monitored by each station, and if a problem is detected, the stations automatically switch their mode of operation to bypass the detected problem.

6 Claims, 11 Drawing Figures

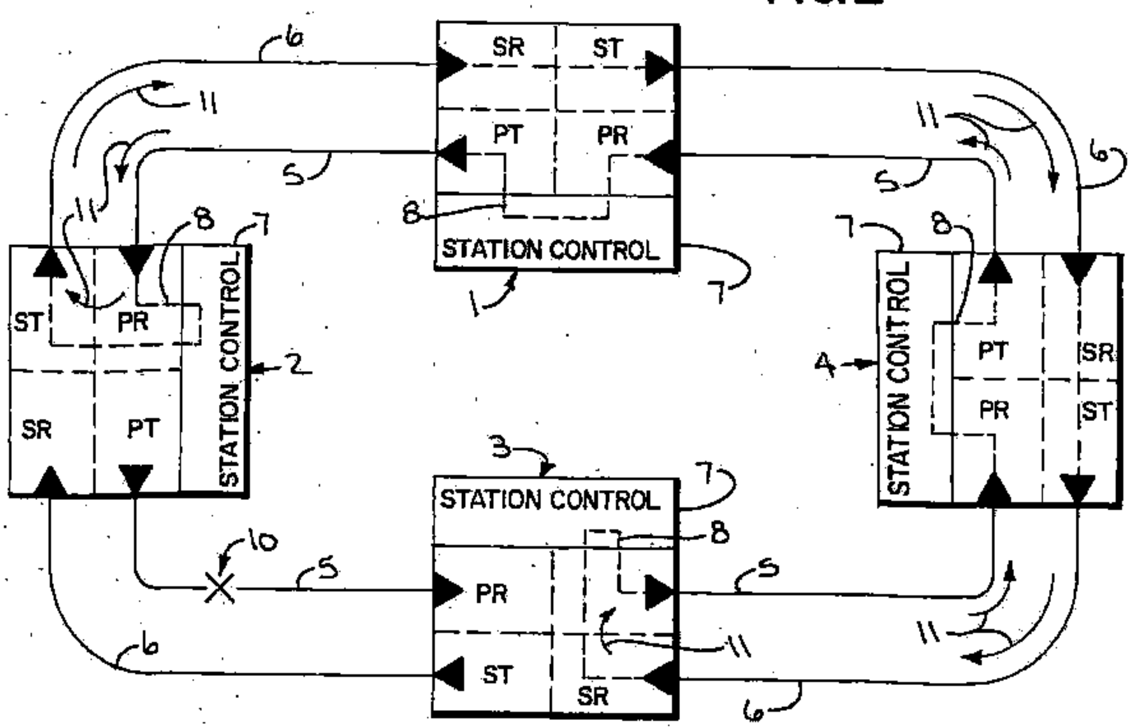




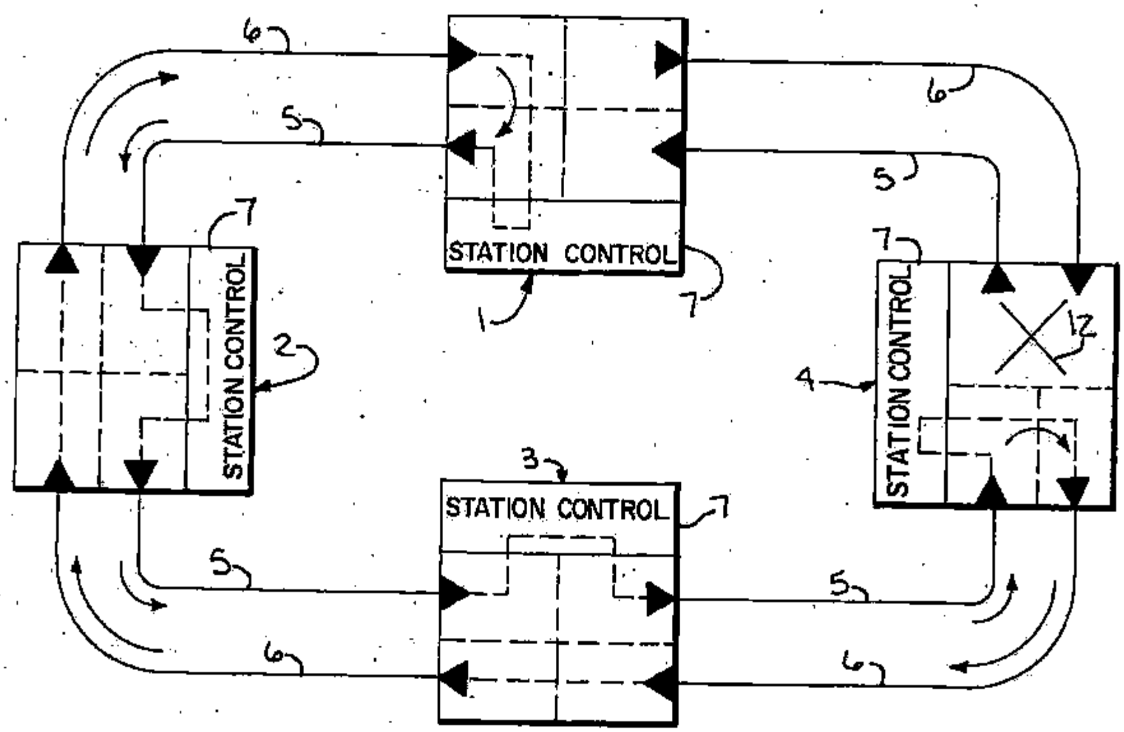
SR
ST
PT
PR
STATION CONTROL
1
2
3
4
5
6
7
8
ST
PR
SR
PT
STATION CONTROL

FIG. 1

FIG. 2



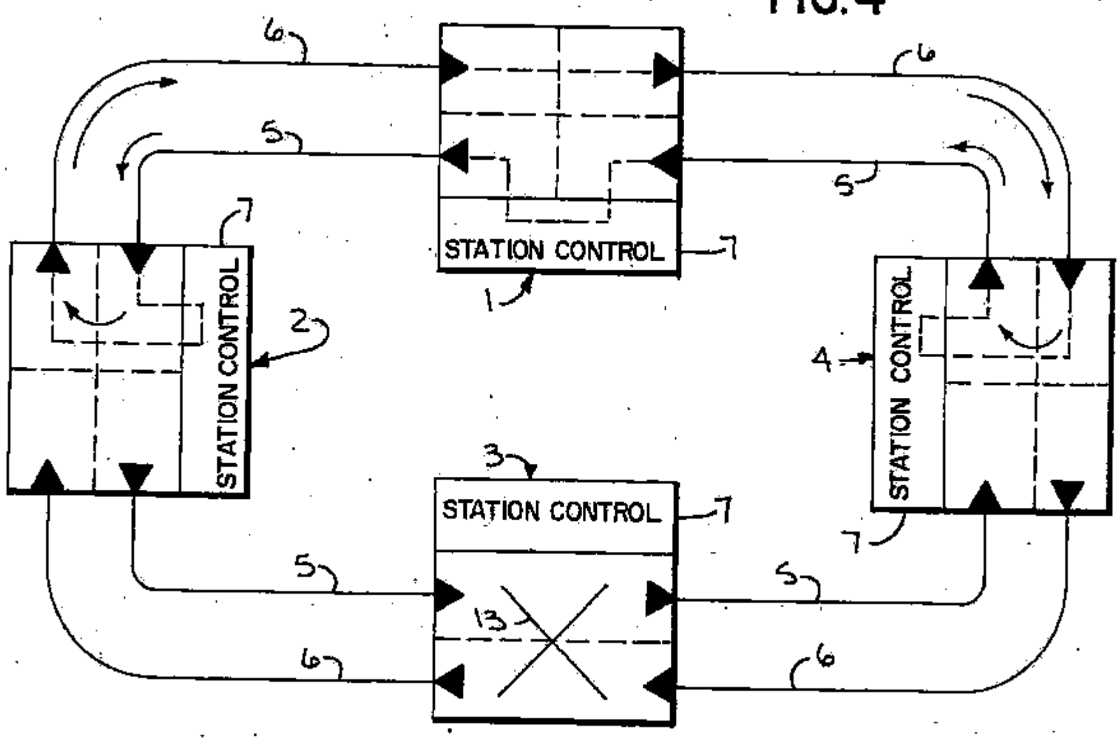
SR
ST
PT
PR
STATION CONTROL
1
2
3
4
5
6
7
8
10
11



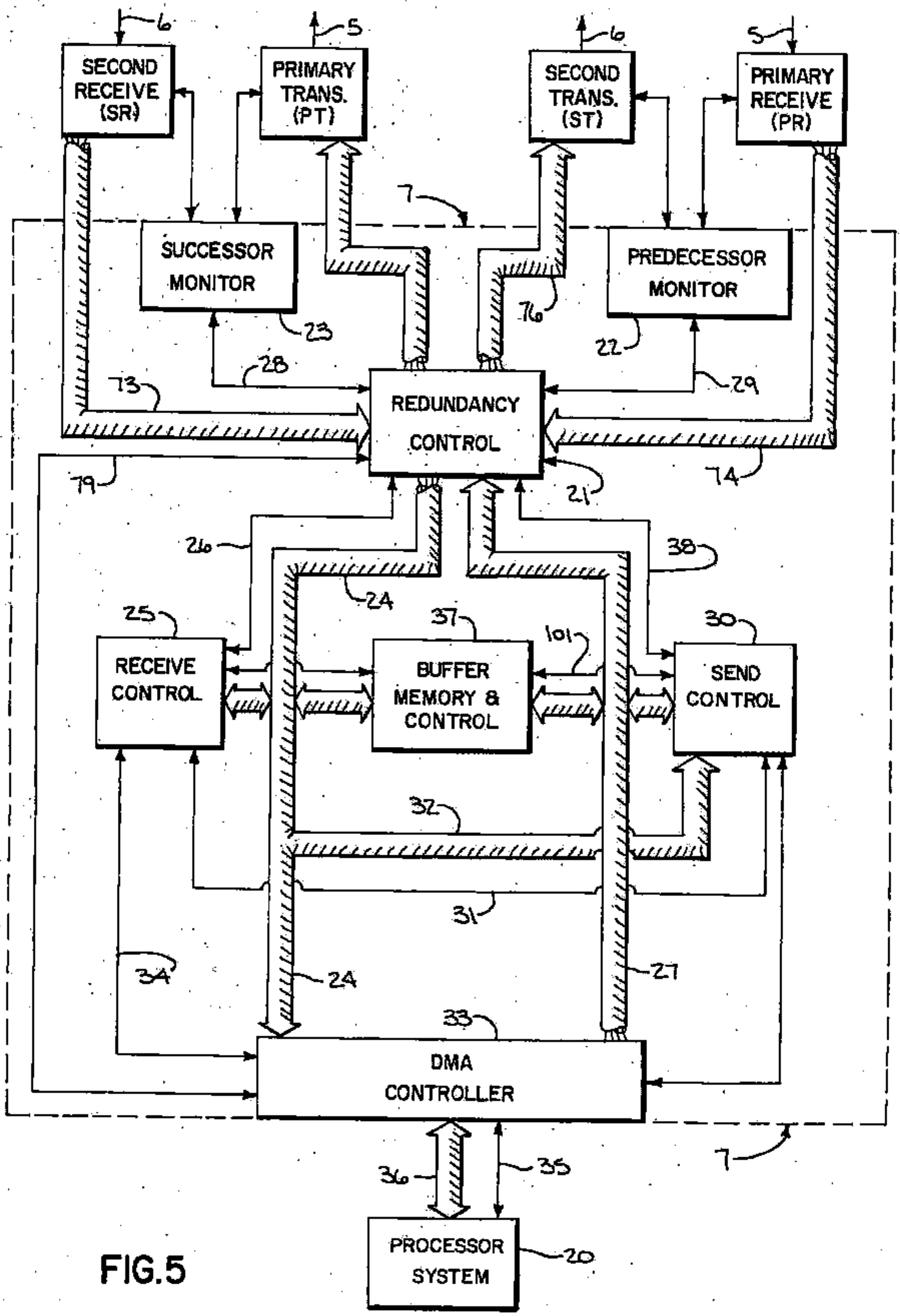
6
5
6
5
7
STATION CONTROL
7
1
STATION CONTROL
2
7
STATION CONTROL
12
4
3
STATION CONTROL
7
5
5
6
6

FIG.3

FIG.4

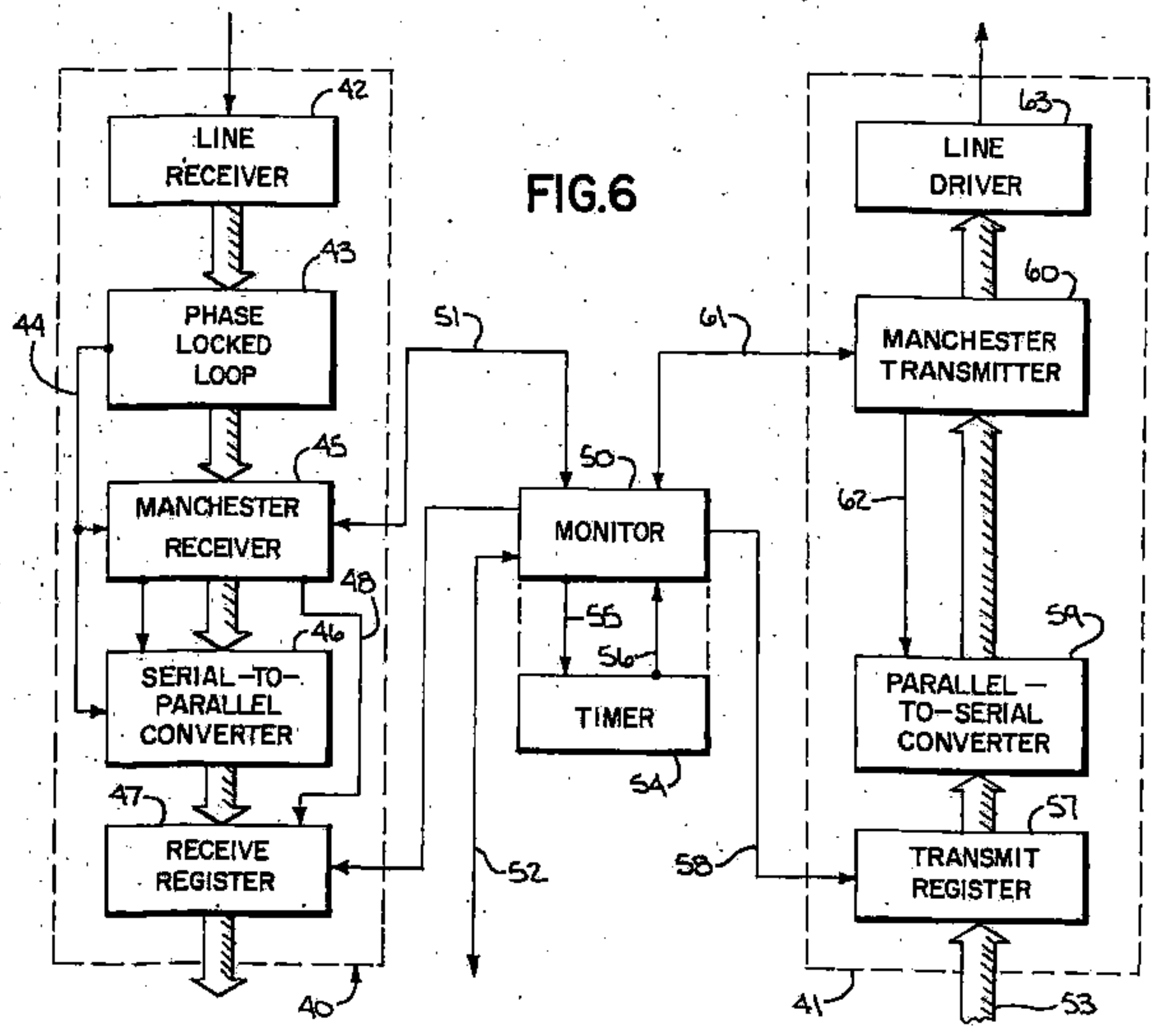


6
5
6
5
7
STATION CONTROL
7
1
STATION CONTROL
2
STATION CONTROL
4
3
STATION CONTROL
7
7
5
5
13
6
6



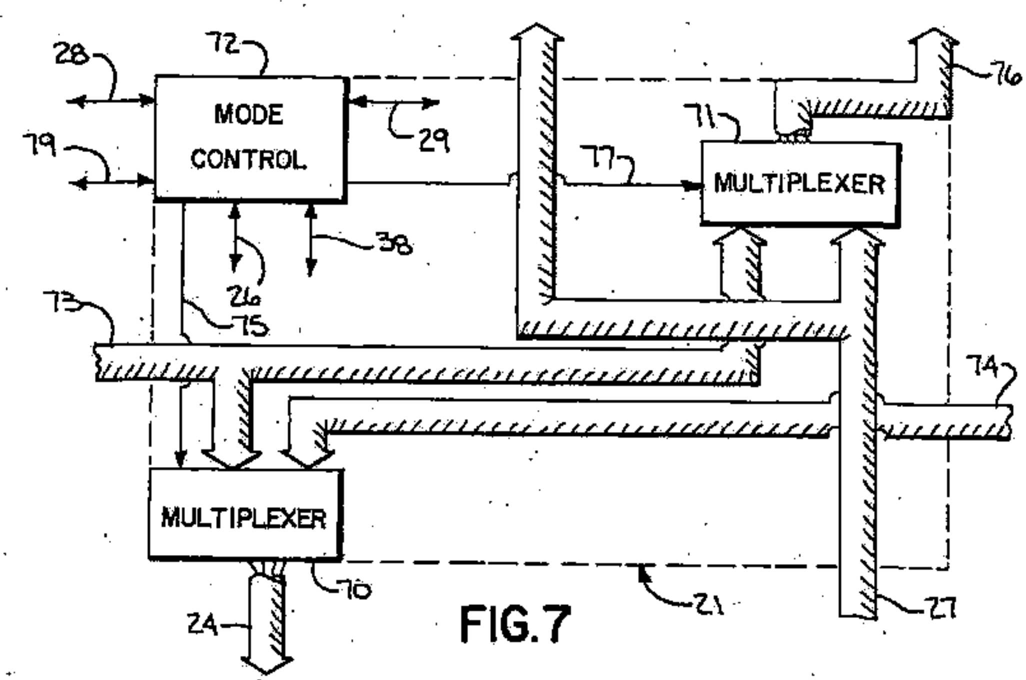
6
5
6
5
SECOND RECEIVE (SR)
PRIMARY TRANS. (PT)
SECOND TRANS. (ST)
PRIMARY RECEIVE (PR)
7
SUCCESSOR MONITOR
PREDECESSOR MONITOR
23
76
22
28
73
29
REDUNDANCY CONTROL
79
74
21
26
38
25
24
37
101
30
RECEIVE CONTROL
BUFFER MEMORY & CONTROL
SEND CONTROL
32
31
34
24
27
33
DMA CONTROLLER
7
36
35
PROCESSOR SYSTEM
20

FIG.5



LINE RECEIVER
PHASE LOCKED LOOP
MANCHESTER RECEIVER
SERIAL-TO-PARALLEL CONVERTER
RECEIVE REGISTER
MONITOR
TIMER
LINE DRIVER
MANCHESTER TRANSMITTER
PARALLEL-TO-SERIAL CONVERTER
TRANSMIT REGISTER

FIG.6



MODE CONTROL
MULTIPLEXER
MULTIPLEXER

FIG.7

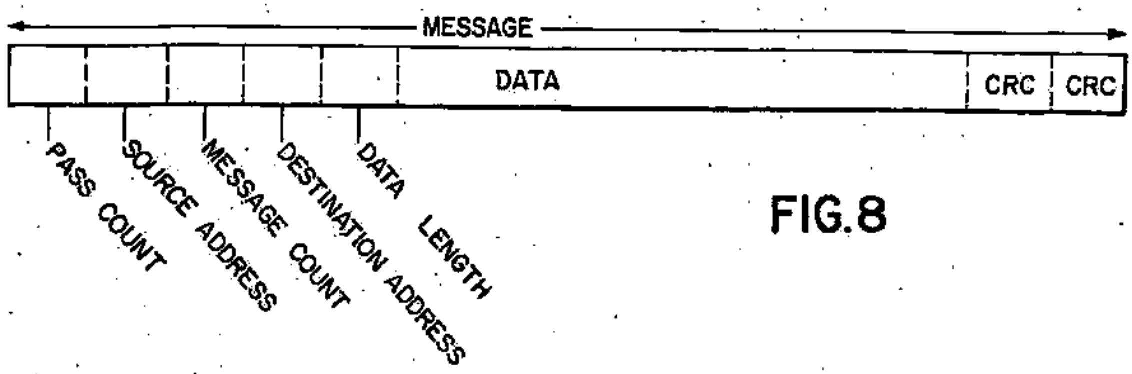

MESSAGE
DATA
CRC
CRC
PASS COUNT
SOURCE ADDRESS
MESSAGE COUNT
DESTINATION ADDRESS
DATA LENGTH

FIG.8

FIG.9

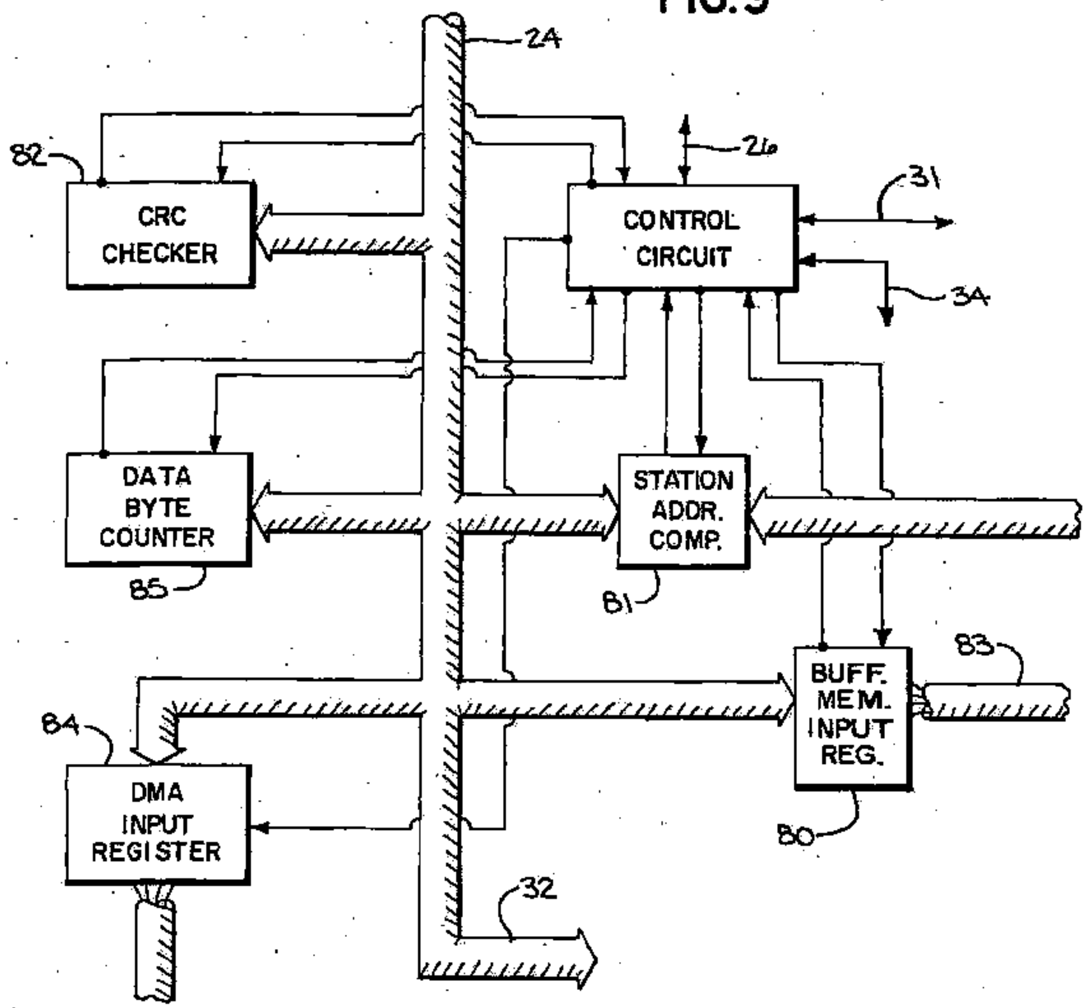
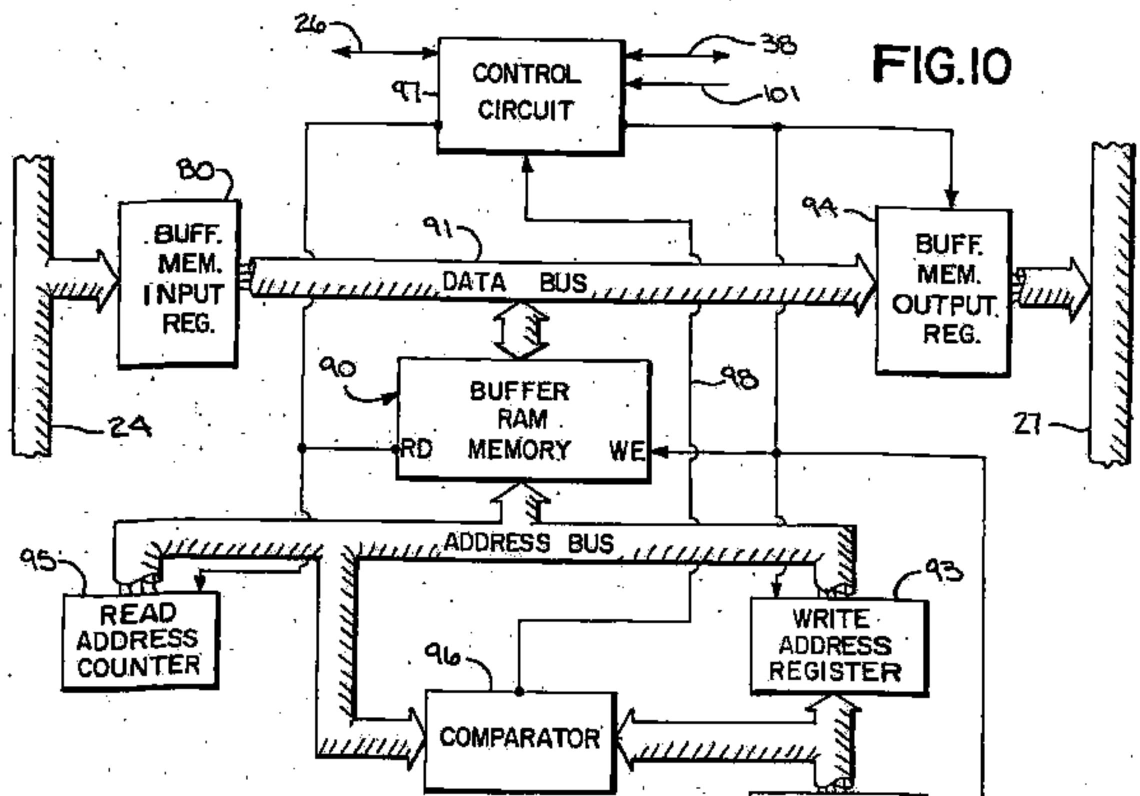
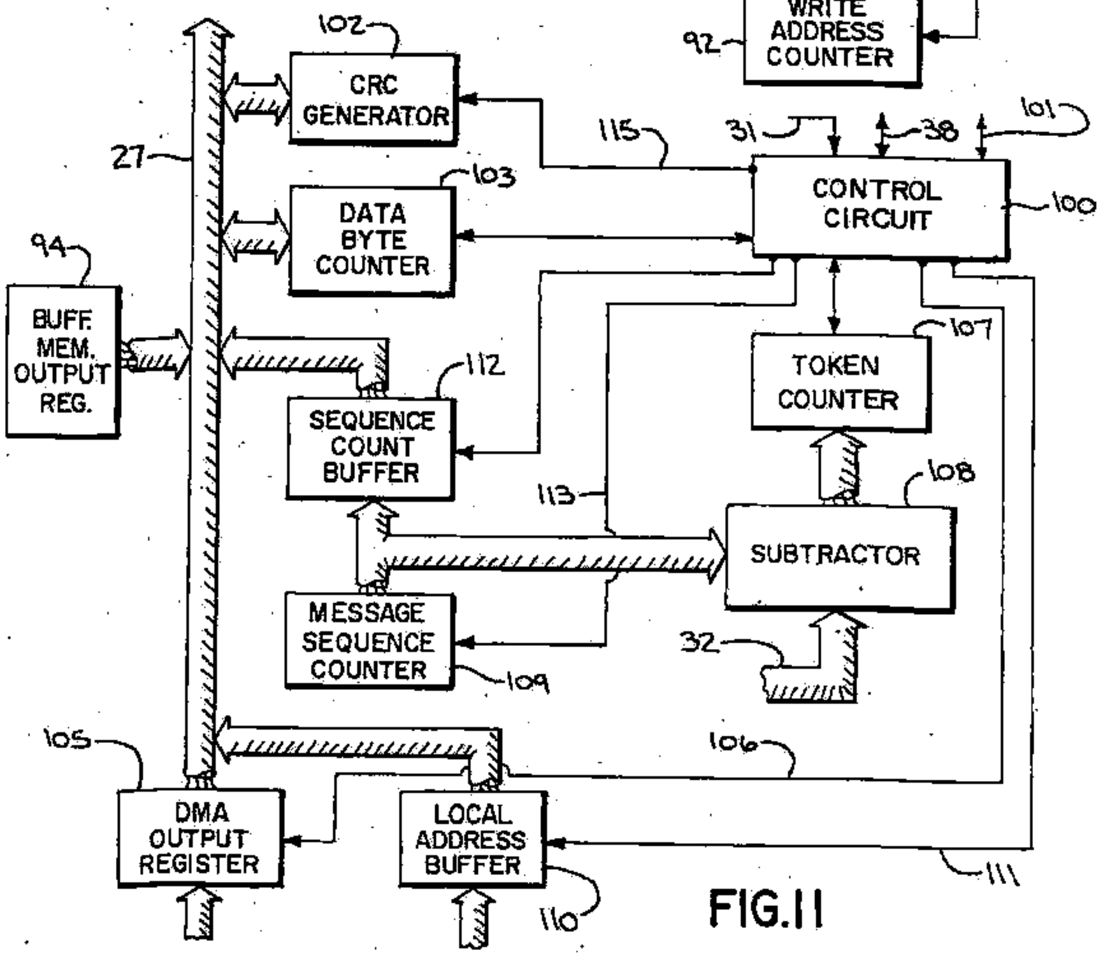

24
26
31
34
82
CRC CHECKER
CONTROL CIRCUIT
DATA BYTE COUNTER
85
STATION ADDR. COMP.
81
83
BUFF. MEM. INPUT REG.
80
84
DMA INPUT REGISTER
32

FIG. 10



26
CONTROL CIRCUIT
97
38
101
80
BUFF. MEM. INPUT REG.
91
DATA BUS
94
BUFF. MEM. OUTPUT REG.
24
90
BUFFER RAM MEMORY
RD
WE
98
27
ADDRESS BUS
95
READ ADDRESS COUNTER
93
WRITE ADDRESS REGISTER
96
COMPARATOR
WRITE ADDRESS COUNTER
92



102
CRC GENERATOR
27
115
31
38
101
CONTROL CIRCUIT
100
103
DATA BYTE COUNTER
94
BUFF. MEM. OUTPUT REG.
112
107
TOKEN COUNTER
SEQUENCE COUNT BUFFER
108
113
SUBTRACTOR
MESSAGE SEQUENCE COUNTER
109
32
105
106
DMA OUTPUT REGISTER
LOCAL ADDRESS BUFFER
111
110

FIG. 11

COMMUNICATIONS NETWORK WITH STATIONS THAT DETECT AND AUTOMATICALLY BYPASS FAULTS

BACKGROUND OF THE INVENTION

The field of the invention is industrial control systems such as process controllers, numerical controls and programmable controllers, and particularly, communication systems for connecting such controllers together in a network.

Historically, industrial control communications networks have been organized into star, multidrop, or ring configurations. In a star configuration, one controller, or "node", forms the center and acts as the network "master". Separate lines extend from this master node to all of the other "slave" nodes. In a multidrop network such as that disclosed in U.S. Pat. No. 4,319,338, a communication line, or data trunk, connects to a plurality of nodes by drop lines. In multidrop networks a single node may act as the network master, mastership may be transferred between nodes by passing a "token", or mastership may be transferred between nodes after a polling process determines which node requires control of the network. Also, in some multidrop networks contention schemes are employed to avoid the need for identifying a master node. In such systems each node "contends" for access to the data trunk, and when access is obtained, a message may be sent directly to any other node in the network. Special hardware is required to detect "collision" of messages on the data trunk.

With a ring configuration each node is linked to two other nodes in a loop arrangement. Messages are relayed around the loop from one node to the next. Messages are removed from the ring by the destination node, or if the message travels full circle, it is removed by the originating node. Because all communications is lost if any single node fails in a ring network, it is common practice to provide a second, or redundant, ring which is switched into operation if the primary ring fails. In a typical installation the primary ring and secondary ring are located adjacent to each other, and if an accident occurs which damages the data link for one ring, it is likely that the other data link will be damaged as well. When both rings are damaged, the entire communication system is closed down.

SUMMARY OF THE INVENTION

The present invention relates to an industrial communication network comprised of a plurality of nodes connected in a primary ring and a secondary ring configuration by twin data links. Each node includes a monitor which is in continuous communication with the monitor in the predecessor node and with the monitor in the successor node, and which is operable to detect a failure in such communications. Each node also includes a redundancy control which is operable in response to signals from the monitor to place the node in one of four states: (1) receive data from the predecessor node on the primary ring and transmit data to the successor node on the primary ring; (2) receive data from the predecessor node on the primary ring, transmit data to the successor node on the primary ring, receive data from the successor node on the secondary ring and transmit this same data to the predecessor node on the secondary ring; (3) receive data from the predecessor node on the primary ring and transmit data to the predecessor node on the secondary ring; and (4) receive data from the successor node on the secondary ring and transmit data to the successor node on the primary ring.

When the network is fully operable all nodes are in mode one and data is transmitted around the primary ring in one direction. If proper communications is lost between any two nodes, this is detected by their monitors and data is diverted onto the secondary ring and flows in the opposite direction. The node to one side of the "break" enters mode three, the node to the other side of the break enters mode four and the remaining nodes enter mode two. Communications between all nodes in the network may thus be maintained despite a break in both rings.

A general object of the invention is to provide a reliable communications network suitable for industrial environments. The monitor in each node continuously communicates through both the primary and secondary rings with adjacent nodes. When a fault is detected the monitor signals the redundancy control and the node is switched to another mode of operation to effectively bypass the detected fault.

Another object of the invention is to minimize the installation cost of the communications network. Because the system can effectively bypass a break in both rings, it is not necessary to physically separate the cables which link the nodes in the ring. Both cables can be installed at the same time thus reducing the installation time and cost over prior redundant ring networks.

Yet another object of the invention is to promptly detect a fault condition in the network and reroute message data around the fault with minimal loss of data and minimal delay. This is achieved by the monitor circuits in each node which are in continuous communication with the monitor circuits in adjacent nodes. A fault may thus be detected even when message data is not being conveyed, and the nodes are then switched to an appropriate mode without delay. No polling messages for locating the fault nor messages commanding mode changes after a fault is located are required.

The foregoing and other objects and advantages of the invention will appear from the following description. In the description, reference is made to the accompanying drawings which form a part hereof, and in which there is shown by way of illustration a preferred embodiment of the invention. Such embodiment does not necessarily represent the full scope of the invention, however, and reference is made therefore to the claims herein for interpreting the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1–4 are schematic diagrams of an industrial control network which employs the present invention and which show the network in a variety of states;

FIG. 5 is an electrical block diagram of a station which forms part of the network of FIGS. 1–4;

FIG. 6 is an electrical schematic diagram of a monitor and associated receiver and transmitter which form part of the station of FIG. 5;

FIG. 7 is an electrical schematic diagram of a redundancy control circuit which forms part of the station of FIG. 5;

FIG. 8 is a schematic representation of a message which is conveyed on the industrial control network of FIGS. 1–4;

FIG. 9 is an electrical schematic diagram of the receive control circuit which forms part of the station of FIG. 5;

FIG. 10 is an electrical schematic diagram of the buffer memory and control circuit which forms a part of the station of FIG. 5; and

FIG. 11 is an electrical schematic diagram of the send control circuit which forms part of the station of FIG. 5.

GENERAL DESCRIPTION OF THE INVENTION

Referring particularly to FIG. 1, a four node communications network includes a set of four stations 1–4 which are connected together in a double ring configuration by a primary data link 5 and a secondary data link 6. Each station 1–4 includes a primary receiver (PR) for receiving data on the primary data link 5 from a predecessor station, and a primary transmitter (PT) for transmitting data to the successor station. Each station 1–4 also includes a station controller 7 which removes data from the network and inserts data addressed to other stations on the network as indicated by the dashed line 8. The stations 1–4 also include secondary receivers (SR) and secondary transmitters (ST) which connect to the secondary data link 6. Whereas the primary receivers and transmitters PR and PT convey data around the primary ring 5 in the counterclockwise direction, the secondary transmitters and receivers SR and ST connect to convey data in the clockwise direction around the secondary ring 6.

Referring still to FIG. 1, when the communications network is fully operational all stations, or nodes, are in mode one. In mode one data is input to each station 1–4 from the predecessor node on the primary ring 5 and transmitted to the successor node on the primary ring 5. No message data is conveyed on the secondary ring 6, although the secondary ring 6 is active to continuously monitor the condition of the network as will be explained in more detail below. Each station 1–4 may originate messages which are conveyed on the primary ring 5 to a designated destination station, and each station 1–4 may remove messages from the ring 5 which are directed to it. In addition, each station 1–4 performs a "repeat" function in which it passes messages from the predecessor node on the primary ring 5 to the successor node.

Referring particularly to FIG. 2, if a break, or fault, should occur in the primary ring 5, as indicated by the "X" 10, each of the stations 1–4 switches to a different mode. The station 2 which precedes the break 10, switches to mode three in which data is received on the primary ring 5 and transmitted on the secondary ring 6 in the reverse direction. On the other hand, station 3 which succeeds the break 10 switches to mode four in which it receives data on the secondary ring 6 and transmits data on the primary ring 5. The remaining stations 1 and 4 switch to mode two in which their primary receiver and transmitter PR and TR operate in their normal fashion, but their secondary receiver and transmitter SR and ST operate to pass through message data on the secondary ring 6. As indicated by the arrows 11, despite the break 10 in the primary ring 5, message data continues to reach all stations 1–4 in the network after these mode changes are made. It should be apparent that even if the secondary ring 6 is broken at the same time between stations 2 and 3, communications is maintained between all stations in the network.

Referring particularly to FIG. 3, if a malfunction should occur in the transmitter/receiver of one station in the network, communications may still be maintained. As indicated by the "X" 12, such a malfunction in station 4 for example, would prevent communications between stations 1 and 4 on both the primary and secondary rings 5 and 6. Station 1 switches to mode four and station 4 switches to mode three to divert messages from the malfunction. Stations 2 and 3 switch to mode two to perform a repeat function on the secondary ring 6.

Referring particularly to FIG. 4, if a malfunction should occur which renders a station inoperable, that station is isolated and communications is maintained on the remainder of the network. As indicated by the "X" 13, if station 3 should become inoperable, station 2 switches to mode three and station 4 switches to mode four to divert message data away from station 3. Station 1 switches to mode two to complete the loop which enables stations 1, 2 and 4 to continue communicating with each other.

As will now be described in more detail, the station controller 7 in each station 1–4 is responsible for monitoring the condition of the network and for switching the station to the appropriate mode. In the preferred embodiment of the invention, wire cables are employed as the links between stations in both the primary ring 5 and secondary ring 6. However, other media such as fiber optics may also be employed.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring particularly to FIG. 5, each station control circuit 7 interfaces the communications media (data links 5 and 6) to a processor system 20. Such processors 20 typically include interface modules on programmable controllers, numerical controls, process controls and general purpose digital computers. Although the station control circuit 7 may be constructed with discrete logic devices, a custom large scale integrated circuit, or a programmed microprocessor system, in the preferred embodiment many of the functions are carried out with field programmable logic sequencers such as the 82S105 manufactured by Signetics, Inc. and with programmable logic arrays such as those sold under the trademark "PAL Series 20" by Monolithic Memories.

Referring still to FIG. 5, the primary receiver (PR) and the secondary transmitter (ST) are connected to a redundancy control circuit 21 in the station control 7. A byte of data may be output by the redundancy control circuit 21 to the secondary transmitter 6, and a byte of data may be input to the redundancy control circuit 21 from the primary receiver (PR). This data flows to and from the predecessor station in the network and it is controlled by a predecessor monitor circuit 22. As will be explained in more detail below, the monitor circuit 22 continuously examines each data byte received from the predecessor station and notifies the redundancy control 21 when valid data is available. The monitor circuit 22 also informs the redundancy control 21 when a fault is detected.

The predecessor monitor circuit 22 signals the redundancy control 21 when a data byte can be sent through the secondary transmitter (ST). If no data is to be transmitted, it is an important feature of the present invention that the predecessor monitor 22 will direct the secondary transmitter (ST) to continuously send "delimiter characters" to the predecessor station on the network. Similarly, such delimiter characters are continuously received at the primary receiver (PR) from the predecessor station between packets of message data. As a result, the monitor circuit 22 is in "continu-

ous" two-way communications with the predecessor station even though message data may be sent or received only sporadically.

If the predecessor monitor circuit 22 detects a fault in communications from the predecessor station, it responds immediately. Such a fault may be sensed in three ways. First, data (either message data or delimiter data) received through the primary receiver (PR) may be interrupted for a preset time interval. Second, the data may be received, but transmission errors at the bit level may be detected; and third, "abort" characters may be received from the predecessor station. In any case, the monitor circuit 22 notifies the redundancy control circuit 21 and directs the secondary transmitter (TR) to send abort characters to the predecessor station rather than delimiter characters.

A successor monitor circuit 23 connects to the secondary receiver (SR), primary transmitter (PT) and the redundancy control 21. It performs the same functions as the monitor 22, but with the connections to the successor station in the network.

The redundancy control 21 is responsible for establishing the mode of operation and channeling message data accordingly. When operating in mode one, the redundancy control 21 receives message data from the primary receiver (PR) and routes it to a receive data bus 24 after alerting a receive control circuit 25 through a control line 26. The redundancy control 21 also receives message data bytes from a transmit bus 27 and routes them to the primary transmitter (PT). No message data is conveyed on the secondary link 6, although the monitor circuits 22 and 23 do continue to send and receive delimiter bytes on the link 6.

If the successor monitor 23 signals through line 28 that a fault has occurred in one or both of the links with the successor station, the redundancy control 21 switches to mode three. In mode three data bytes are still received through primary receiver (PR) and passed to the receiver bus 24, but now the data bytes received from the transmit bus 27 are routed to the secondary transmitter (ST). Communications with the successor station is monitored but no message data is received from or transmitted to the successor mode.

If the predecessor monitor 22 signals through control line 29 that a fault has occurred in the links with the predecessor station, the redundancy control 21 switches to mode four. In mode four message data is received from the secondary receiver (SR) and routed to the receiver bus 24. Message data from the transmit bus 27 is conveyed to the primary transmitter (PT) and no message data is transmitted to or received from the predecessor station.

If while the station is operating normally in mode one a message byte is received by the secondary receiver (SR), the successor monitor 23 signals the redundancy control 21 to switch to mode two. In mode two, message data is received from the primary receiver (PR) and transmitted through the primary transmitter (PT) in the same manner as mode one. However, message data is also received at the secondary receiver (SR) and coupled directly to the secondary transmitter (ST).

Referring still to FIG. 5, the receiver control circuit 25 receives a signal from the redundancy control 21 which indicates that a byte of data is available. The receive control 25 analyzes the message data to determine if the message is to be relayed on to the next station in the network, is to be removed from the network, or is to be conveyed to the processor system 20. Each message includes a source address byte which indicates the source of the message, and the receive control 25 compares this byte with its own station number. If a match is found, the message is removed from the network and a "send control circuit" 30 is notified through control line 31 that one of its messages has returned. Each such message contains a sequence count byte (MAC control byte) which is extracted by the receive control 25 and coupled to the send control circuit 30 through a bus 32. As will be explained below, this MAC control byte is employed to determine the number of messages this station has on the network at any time. It is employed to limit the number of messages placed on the network by any one station.

Each received message also includes a destination address byte and when this corresponds to the station's own address, the receive control circuit 25 notifies a DMA controller 33 through a control line 34. The DMA controller 33 receives each byte in such messages from the receive bus 24 and transmits them to a buffer memory in the processor system 20 through a data bus 36. When the receive control circuit 25 indicates that all bytes have been correctly received, the DMA controller 33 is signalled and it notifies the processor 20 through a control line 35 that the message is accurate.

All received messages which did not originate at the station are relayed to the next station in the network. The receive control 25 in such cases directs the message data to a buffer memory and control circuit 37. The buffer memory and control circuit 37 stores messages in the order which they are received, and in response to commands from the send control circuit 30, these messages are output in the same order to the transmit bus 27.

The redundancy control 21 signals the send control 30 through line 38 when a byte of data can be accepted for transmission to the next station in the network. The send control 30 examines the buffer memory 37 for message data, and if data is available, it is read onto the transmit bus 27 and written to the redundancy control 21. If data is not available in the buffer memory 37, the send control 30 will accept message data from the DMA controller 33. As will be explained in more detail below, before placing such a new message on the network the send control 30 first determines that this station has not exceeded the allowed number of messages on the network. It then creates a new message with data read from the processor system 20 by the DMA controller 33 and applies it one byte at a time to the input of the redundancy control 21.

Referring particularly to FIG. 6, the primary and secondary receivers PR and SR are identically constructed. One such receiver is indicated by dashed line 40 and its matching transmitter is indicated by dashed line 41. The receiver 40 includes a line receiver 42 which converts the data link voltages to TTL/MOS compatible voltage levels. If the data links are fiber optic cables, then the line receiver 42 converts the light signal to TTL/MOS compatible voltage levels.

The signal produced by the line receiver 42 is applied to the input of a phase locked loop 43. This circuit contains a counter which is clocked at eight times the baud rate of the network and which generates a clock signal on line 44 which is synchronized with the digital input signal. This synchronized clock signal is used by a manchester receiver 45 and a serial-to-parallel converter 46 to process each byte of input data. The manchester receiver 45 is a programmable logic sequencer

which decodes the manchester encoded signal from the line receiver 42 and sends each bit to the serial-to-parallel converter 46. The manchester receiver 45 recognizes the boundries between bytes and it signals a receive register 47 through a line 48 when a byte is available at the converter 46. The manchester receiver 45 also signals the monitor 50 when a byte is available at the receive register 47, and it signals the monitor 50 through control line 51 when erroneous signals, or certain control bytes are sensed.

The monitor 50 is a programmable logic sequencer which receives signals from the receiver 40 that indicate its current state. In response to these signals it sends control signals through a line 52 to the redundancy control circuit 21 (FIGS. 5 and 7). The control line 52 corresponds to control lines 28 or 29 in FIG. 5. The monitor 50 also receives signals from the redundancy control circuit 21 through control line 52 when a byte of data is available on bus 53 for transmission.

A timer 54 connects to the monitor 50 and is reset thereby through a control line 55 each time a message data byte or a delimiter byte is received at the manchester receiver 45. If a fault should occur which disrupts the receipt of such data, the timer 54 "times out" and generates an error signal to the monitor 50 through control line 56. As indicated above, such an error indication causes the redundancy control 21 to change the mode of station operation to by-pass the fault.

Referring still to FIG. 6, when the redundancy control 21 signals the monitor 50 that a data byte is available on bus 53, the monitor 50 clocks a transmit register 57 through a control line 58. The data byte is latched in the register 57 and is applied to the inputs of a parallel-to-serial converter 59. The monitor 50 then sends a transmit request signal to a manchester transmitter 60 through control line 61. The manchester transmitter is a programmable logic sequencer which signals the parallel-to-serial converter through a control line 62 when it is ready to accept another byte of data. As the converter 59 shifts out the byte, the manchester transmitter codes the bits and sends them to a line driver 63. The line driver 63 converts the logic level input signals to the cable voltages and currents, or to a light signal if fiber optic cable is used. When message data bytes are not available for transmission, the monitor 50 directs the manchester transmitter 60 to generate delimiter characters. Thus, a continuous stream of serial data is produced by the transmitter 41 to maintain continuous communication with the receiving station on the network. If for any reason this continuous stream of data is not generated or is not received, then the monitor in the receiving station "times out" and a fault is indicated.

The operation of the monitor 50 is identical in each station. The monitor operates according to the following protocol:

(a) When there is no information to transmit and the quality of the data at its receiver is satisfactory, the manchester transmitter 60 is directed to send delimiter characters.

(b) When the redundancy control 21 signals that a byte is to be transmitted and the receiver signal quality is satisfactory, the byte is transmitted.

(c) When the quality of the received data is inadequate, the redundancy control 21 is signalled that the communication link is bad and the manchester transmitter 60 is directed to send abort characters.

(d) When received data quality is restored for a specified time period, the redundancy control 21 is signalled that the communication link is restored.

(e) Received data is passed to the redundancy control when the communication link is good.

(f) If a string of three abort characters is received, the communication link is declared bad by signalling the redundancy control 21.

(g) When two successive delimiter characters are received the communication link is declared good.

(h) The monitor 50 can be directed through control line 52 by the redundancy control 21 to declare the communication link bad.

(i) The monitor 50 increments the first byte in each message (the pass count) received at its receiver 40. If the pass count exceeds a pre-established limit, none of the message bytes are passed on to the redundancy control 21. This function insures that messages are eventually removed from the network.

Referring particularly to FIGS. 5 and 7, the redundancy control 21 is comprised of an input multiplexer 70, an output multiplexer 71, and a mode control circuit 72. The input multiplexer 70 drives the receive bus 24 and it has one input connected to an 8-bit input bus 73 which connects to the secondary receiver (SR). The other multiplexer input connects to an 8-bit input bus 74 which is driven by the primary receiver (PR). The multiplexer 70 is controlled by the mode control 72 through a control line 75 to couple the receiver bus 24 to either the input bus 73 or the input bus 74.

The output multiplexer 71 drives an 8-bit output bus 76 which connects to the secondary transmitter (ST). One input to the multiplexer 71 is driven by the transmit bus 27 and its other input is driven by the 8-bit input bus 73. Data on either the transmit bus 27 or the input bus 73 may thus be coupled to the secondary transmitter (ST) by controlling the state of a control line 77.

Referring particularly to FIGS. 5 and 7, the mode control 72 is a programmable logic sequencer which is responsive to input signals on control lines 26, 28, 29 and 38 to determine the mode of operation. The mode is then implemented by controlling the multiplexer select lines 75 and 77. For example, if the successor monitor 23 indicates through control line 28 that communications with the successor station on the network has been disrupted, the mode control 72 switches the station to mode three. This is accomplished by directing the multiplexer 70 to receive input data from bus 74 and directing the multiplexer 71 to output data on the bus 76 from the transmit bus 27. The mode control 72 continues to monitor signals from the successor monitor 23, but signals indicating the receipt of data or the successful transmission of data is limited to control line 29 which connects to predecessor monitor 22. A control line 79 also connects the mode control 72 to the DMA controller 33, and through this line the processor system 20 can determine the station mode. Also, the processor system 20 can write a mode command to the DMA controller 33 which directs the mode control 72 to change the station mode. This capability is used, for example, during power-up when it is assumed that communications is fully operable and that the station should be operating in mode one.

Referring particularly to FIGS. 5, 8 and 9, each message which is received by the station and passed to the receive bus 24 by the redundancy control 21 is comprised of a number of bytes of data. The receive control

circuit 25 is signaled through control line 26 when the message data is available, and the first byte of the message (the pass count) is latched in a buffer memory input register 80. The next byte of the message is the source address of the message and it is applied to one input of a station address comparator 81 where it is compared with a station address. The station address is received from the DMA controller 33 through a bus 82, and when identity is found, the message data is to be removed from the network. Otherwise, the message data is passed on to the next station in the network through the memory buffer and control 37.

If the local address agrees with the source address byte in the message, the message is to be removed, but since the CRC must be checked, a CRC checker 82 will be enabled to tally all further bytes received in this message. When the next byte (message count) is received, a signal is sent by the receive control circuit to the send control 30 indicating that the message count is on the bus 32. The send control 30 employs the message count byte to keep track of the number of messages this station has placed on the network. When the entire message has been received, the CRC checker 82 is directed to check the last two bytes to determine if the message has been accurately received. If so, the message is removed from the network and the receive control 25 awaits receipt of the next message packet from the redundancy control 21.

If the source address does not compare with the station number, the message is passed on to the buffer memory and control 37. In such case, each received byte is latched in the buffer memory input register 80 and is then clocked onto a bus 83 which connects to the buffer memory 37. In addition, the fourth byte of each message is a destination address which is applied to the station address comparator 81. If identity is found, the data bytes in the message are also clocked into a DMA input register 84 so that they may be sent to the processor 20.

The fifth byte in each message indicates the number of data bytes in the message. This data length byte is clocked into a data byte counter 85 which is then decremented as each subsequent data byte is processed. When the counter 85 reaches zero, the data has been processed and the next two bytes are applied to the CRC checker 82 to determine if an accurate transmission has occurred. The DMA controller 33 is then signaled through control line 34 that the message data is accurate and the DMA controller 33 may in turn signal the processor 20.

Referring particularly to FIGS. 5 and 10, the buffer memory and control 37 receives message data from the receive bus 24 which is to be retransmitted to the next station in the network. Each byte of the message is input through the buffer memory input register 80 and is written into a buffer RAM memory 90 through a data bus 91. The message bytes are stored at successive memory addresses and successive messages are stored in the memory 90 in the order in which they are received. A write address counter 92 is incremented each time a byte is stored in the memory 90, and the address which it generates is coupled to the address terminals of the memory 90 through a write address register 93.

Messages stored in the buffer memory 90 are read out one byte at a time and coupled through the data bus 91 to a buffer memory output register 94. A read address counter 95 is incremented each time a byte is read from the memory 90, and as a result, the message data stored

in the memory 90 is read out in the same order as it was stored. A comparator 96 receives both the read and write address data and when a match is detected, a control circuit 97 is signaled through line 98 that the buffer memory 90 is empty. The control circuit 97 is a programmable logic sequencer which generates the control signals to the various elements associated with the buffer memory 90. It signals the receive control 25 through line 26 when it is ready to receive data at register 80, and it signals the send control 30 through line 38 when a data byte is available for transmission at the output register 94.

Referring particularly to FIGS. 5 and 11, the send control 30 conveys messages to the redundancy control 21 which may originate from either the buffer memory and control 37 or the DMA controller 33. As in the buffer memory 37, these are conveyed to the redundancy control 21 for transmission on the network. When the buffer memory 37 is emptied, then messages originating from the processor system 20 may be placed on the network. When a message is to be sent which originates in the buffer memory 37, a control circuit 100 in the send control circuit 30 signals the buffer control to output a byte to the buffer memory output register 94. This message data is applied to the redundancy control 31 through the transmit bus 27. The control circuit 100 signals the redundancy control 21 through control line 38 as each message byte becomes available. As each message byte is applied to the redundancy control 21, a CRC generator 102 is signaled to input the byte. In addition, when the data length byte appears at the output register 94, it is loaded into a data byte counter 103. The data byte counter 103 is decremented as each data byte is subsequently conveyed to the redundancy control 21, and when it reaches zero, the control circuit 100 is alerted. The CRC generator 102 then sequentially places its two CRC bytes on the transmit bus 27 for application to the redundancy control 21.

The message data may in the alternative originate from the station's processor 20 if two conditions are met. Such message data is output through a DMA output register 105, and CRC generator 102 operates in the same manner. The DMA output register 105 receives message data from the DMA controller 33 and it is enabled by the control circuit 100 through line 106.

Message data which originates at the station's processor 20 may be inserted into the stream of data flowing through the station if the buffer memory 37 is empty and the station does not already have an excessive number of messages on the network. The first condition is sensed by the comparator 96 in the buffer memory and control circuit 37 (FIG. 10). The control circuit 97 signals this condition to the control circuit 100 in the send control 30 (FIG. 11) through line 38. The second condition is established by a token counter 107 which keeps track of the number of messages this station has placed on the network. The token counter is incremented by the control circuit 100 each time an original message is sent and it is preset to a count determined by a subtractor 108 each time one of the station's messages is returned to the receive control 25. As indicated above, the message count byte in each such received message is applied through the bus 32 to one set of inputs on the subtractor 108. A message sequence counter 109 connects to the other set of subtractor inputs, and this counter 109 indicates the value of the message count byte in the last station message inserted on the network. The difference between this latest mes-

sage count and the message count value in the most recently returned station message indicates the number of station messages currently on the network. If this number exceeds a preset value, the control circuit 100 is inhibited from inserting further station messages until station messages currently on the network are returned.

When a station message is inserted on the network, the CRC generator 102 is preset to zero and outputs this value as the "pass count" byte to the transmit bus 27. The control circuit 100 signals the redundancy control 21 through line 38 that a byte is available for transmission. After the pass count byte is transmitted, a local address buffer 110 is enabled through control line 111 and the station's own address is conveyed to the redundancy control 21 for transmission. The CRC generator 102 is also enabled to tally this source address byte and all subsequent bytes in the message.

The next byte in the station's message is the message count. This byte is applied to the transmit bus 27 by a sequence count buffer 112 which connects to the output of the message sequence counter 109. The counter 109 is then incremented one count by enabling control line 113. The destination address byte is then read from the DMA output register 105, followed by the data length byte. Both of these bytes are conveyed to the redundancy control 21 and the data length byte is clocked into the data byte counter 103. The data bytes which follow are coupled from the DMA output register 105 to the redundancy control 21 and the data byte counter 103 is decremented. When the counter 103 reaches zero, the CRC generator 102 is signaled through control line 115 to place the two CRC bytes on the bus 27 for transmission.

It should be apparent from the above description that many variations are possible from the preferred structure. For example, many of the functions which are carried out by discrete hardware components in the preferred embodiment may be carried out by a programmed microprocessor. On the other hand, these same hardware components may also be constructed as a custom large scale integrated circuit where the economics justify the initial design costs. The present invention is independent of the particular technology which is chosen.

The invention claimed is:

1. In a communication network having a plurality of station nodes connected together in a ring configuration by a primary data link which conveys data around the ring from station to station in one direction and a secondary data link which conveys data around the ring from station to station in the other direction, an improved station which comprises:

a primary receiver connected to the primary data link to receive data from a predecessor station on the network;

a primary transmitter connected to the primary data link to transmit data to a successor station on the network;

a secondary transmitter connected to the secondary data link to transmit data to the predecessor station on the network;

a secondary receiver connected to the secondary data link to receive data from the successor station on the network;

a predecessor monitor connected to the primary receiver and the secondary transmitter, said predecessor monitor being operable:

(a) to detect poor data quality at the primary receiver;

(b) to detect the receipt of abort data by the primary receiver; and

(c) to generate a first error signal when either of the conditions in (a) or (b) is detected; and

a successor monitor connected to the primary transmitter and the secondary receiver, said successor monitor being operable:

(d) to detect poor data quality at the secondary receiver;

(e) to detect the receipt of abort data by the secondary receiver; and

(f) to generate a second error signal when either of the conditions in (d) or (e) is detected; and

a redundancy control circuit connected to the predecessor monitor and the successor monitor, the redundancy control circuit being responsive to the generation of the first or second error signals to control the mode of operation of the station and to thereby direct the conveyance of message data between the station and the predecessor and successor stations;

when the station is in mode one message data is received by the primary receiver and transmitted by the primary transmitter, the secondary receiver receives data from the successor station, and the secondary transmitter transmits delimiter data to the predecessor station;

where the station is switched to mode four when the first error signal is generated and all message data is received at the secondary receiver and transmitted by the primary transmitter; and

where the station is switched to mode three when the second error signal is generated and all message data is received at the primary receiver and transmitted by the secondary transmitter.

2. The improved station as recited in claim 1 in which the redundancy control circuit is responsive to message data received by the secondary received when the station is in mode one to switch the station to mode two in which message data received at the primary receiver continues to be transmitted by the primary transmitter and all message data received at the secondary receiver is transmitted directly by the secondary transmitter.

3. The improved station as recited in claim 1 in which the redundancy control circuit includes:

a first multiplexer having one input coupled to the primary receiver, a second input coupled to the secondary receiver, and an output coupled to a receive bus;

a second multiplexer having one input coupled to the secondary receiver, a second input coupled to a transmit bus, and an output coupled to the secondary transmitter.

4. The improved station as recited in claim 1 in which each monitor is operable to direct its associated transmitter to send abort data when the monitor detects poor data quality at its associated receiver.

5. The improved station as recited in claim 4 in which each monitor is operable to direct its associated transmitter to send delimiter data when the monitor does not detect poor data quality at its associated receiver and there is no message data available for transmission by its associated transmitter.

6. The improved station as recited in claim 1 in which each monitor is responsive to the value of a pass count byte contained in message data received at its associated receiver to remove the message data associated with the pass count byte from the communications network when the arithmetic value of the pass count byte exceeds a preset amount.

* * * * *

EXHIBIT E

What is claimed is:

1. In a communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each node including subrate transmitters with associated multiplexers and demultiplexers with associated subrate receivers, the improved node comprising

monitoring means, associated with the rings, for evaluating the integrity of the multiplexed subrate communications on each of the associated rings, and

insertion means, associated with the demultiplexers and said monitoring means, for inserting an error signal on designated ones of the subrate communications in response to said monitoring means detecting a lack of integrity on the multiplexed subrate communications on at least one of the associated rings.

2. In the communications network of claim 1, the improved node further comprising selector means associated with the demultiplexers for selecting, in response to the detection of said error signal on one of the subrate communications, another of the subrate communications that does not contain said error signal.

3. In the communications network of claim 1, the improved node wherein the multiplexers multiplex selected subrate communications containing said error signal into a multiplexed subrate communication for transmission onto the associated rings.

4. A communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction

and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each of said nodes including subrate transmitters and subrate receivers and further comprising:

monitoring means for evaluating the integrity of the multiplexed subrate communications on each of the associated rings,

means for demultiplexing the multiplexed subrate communications on the associated ring into subchannels, wherein at least one of said subchannels is sent to a corresponding receiver,

insertion means associated with said demultiplexing means to insert an error signal on each of said subchannels in response to said monitoring means detecting a lack of integrity on the multiplexed subrate communications on one of the associated rings,

selector means associated with said demultiplexing means for selecting, in response to the detection of said error signal on one of the subchannels, one of the other subchannels, and

multiplexing means for multiplexing subchannels and inserting multiplexed subrate communications onto the associated ring.

5. A communications network having a first grouping of nodes interconnected by a first ring arrangement, a second grouping of nodes interconnected by a second ring arrangement, each ring arrangement conveying multiplexed subrate communications in a first direction from node to node and conveying multiplexed subrate communications in a second direction from node to node, and each node comprises subrate transmitters with associated multiplexers and demultiplexers with associated receivers, and wherein

each node comprises

monitoring means associated with its ring arrangement for evaluating the integrity of the multiplexed subrate communications on the associated ring,

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insertion means, associated with its demultiplexers and its monitoring means, for inserting an error signal on designated ones of said subrate communications in response to said monitoring means detecting a lack of integrity on said multiplexed subrate communications on its said associated ring arrangement, and

selector means, associated with its demultiplexers, for selecting, in response to the detection of said error signal on a subrate communication, a subrate communication that does not contain an error signal, and

wherein a preselected node of the first ring arrangement comprises;

means for directing at least one subrate communication to the second ring arrangement and corresponding subrate communications from the second ring arrangement for multiplexing onto multiplexed subrate communications on the first ring arrangement.

6. The network of claim 5 wherein said subrate communication directed to the second ring arrangement is received by a preselected node of the second ring arrangement for multiplexing into multiplexed subrate communications around the second ring arrangement,

and wherein the subrate communications directed to the first ring arrangement originates at said preselected node of the second ring arrangement.

7. In a communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed-subrate communications around the first ring from node to node in one direction and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each node including subrate transmitters with associated multiplexers and demultiplexers with associated receivers, an improved

Lau 1

method associated with each node comprising the steps of

evaluating the integrity of the multiplexed subrate communications on each of said associated rings with monitoring means, and

inserting an error signal on designated ones of said subrate communications in response to said monitoring means detecting a lack of integrity on said multiplexed communications on at least one of said associated rings.

8. The method as recited in claim 7 further comprising the step of selecting, response to the detection of said error signal on said at least one of the subrate communications, another of the subrate communications that does not contain an error. -

EXHIBIT F

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

SERIAL NUMBER	FILING DATE	FIRST NAMED APPLICANT		ATTORNEY DOCKET NO.
07/152,238	02/04/88	LAU	C	1

JAMES W. FALK
BELL COMMUNICATIONS RESEARCH, INC.,
290 WEST MOUNT PLEASANT AVE.
LIVINGSTON, NJ 07039

EXAMINER	
CHIN,W	
ART UNIT	PAPER NUMBER
263	3

DATE MAILED: 10/06/88

This is a communication from the examiner in charge of your application.

COMMISSIONER OF PATENTS AND TRADEMARKS

[X] This application has been examined [ ] Responsive to communication filed on ______ [ ] This action is made final.

A shortened statutory period for response to this action is set to expire 3 month(s), — days from the date of this letter.
Failure to respond within the period for response will cause the application to become abandoned. 35 U.S.C. 133

Part I THE FOLLOWING ATTACHMENT(S) ARE PART OF THIS ACTION:

1. [X] Notice of References Cited by Examiner, PTO-892.
2. [X] Notice re Patent Drawing, PTO-948.
3. [X] Notice of Art Cited by Applicant, PTO-1449
4. [ ] Notice of Informal Patent Application, Form PTO-152
5. [X] Information on How to Effect Drawing Changes, PTO-1474
6. [X] List of Bonded Draftsmen

Part II SUMMARY OF ACTION

1. [X] Claims 1-8 are pending in the application.

   Of the above, claims ______ are withdrawn from consideration.

2. [ ] Claims ______ have been cancelled.
3. [ ] Claims ______ are allowed.
4. [X] Claims 1-8 are rejected.
5. [ ] Claims ______ are objected to.
6. [ ] Claims ______ are subject to restriction or election requirement.
7. [X] This application has been filed with informal drawings which are acceptable for examination purposes until such time as allowable subject matter is indicated.
8. [ ] Allowable subject matter having been indicated, formal drawings are required in response to this Office action.
9. [ ] The corrected or substitute drawings have been received on ______. These drawings are [ ] acceptable; [ ] not acceptable (see explanation).
10. [ ] The [ ] proposed drawing correction and/or the [ ] proposed additional or substitute sheet(s) of drawings, filed on ______ has (have) been [ ] approved by the examiner. [ ] disapproved by the examiner (see explanation).
11. [ ] The proposed drawing correction, filed ______, has been [ ] approved. [ ] disapproved (see explanation). However, the Patent and Trademark Office no longer makes drawing changes. It is now applicant's responsibility to ensure that the drawings are corrected. Corrections MUST be effected in accordance with the instructions set forth on the attached letter "INFORMATION ON HOW TO EFFECT DRAWING CHANGES", PTO-1474.
12. [ ] Acknowledgment is made of the claim for priority under 35 U.S.C. 119. The certified copy has [ ] been received [ ] not been received
    [ ] been filed in parent application, serial no. ______; filed on ______.
13. [ ] Since this application appears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 O.G. 213.
14. [ ] Other

1. The drawings are objected to because the figures lack descriptive labels. Correction is required.

2. Applicant is required to submit a proposed drawing correction in response to this Office action. However, correction of the noted defect can be deferred until the application is allowed by the examiner.

3. Claims 1-8 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

Claim 1, page 8, lines 10-11, "the improved node" lacks antecedent basis. Claim 1, page 8, line 12, it is unclear what "the rings" is referring to, as there is no clear antecedent for this terminology.

Claim 1, page 8, lines 14 and 20 respectively, it is unclear what structure "the associated rings" is referring to. Claim 4, page 9, lines 6-7, it is unclear what "the associated rings" are, as it is unclear as to what the rings are being associated with and there is no clear antecedent for a first and second ring only. Claim 4, page 9, lines 10-11, it is unclear if "a corresponding receiver" is meant to refer to one of the subrate receivers previously recited. Claims 5-8 are rejected for similar reasons as those set forth above.

4. Claims 1-8 would be allowable if rewritten or amended to overcome the rejection under 35 U.S.C. 112.

5. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. Prior art cited is typical of prior fault recovery tech-

niques used in multiple ring communication systems.

6. Any inquiry concerning this communication should be directed to Wellington Chin at telephone number 703-557-3374.

W. Chin:vj

703-557-3374

10-03-88 WC

Douglas W. Olms

DOUGLAS W. OLMS
PRIMARY EXAMINER
GROUP 263

TO SEPARATE, FOLD TOP AND BOTTOM EDGES, SNAP—APART AND DISCARD CARBON

FORM PTO-892 (REV. 3-78) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

NOTICE OF REFERENCES CITED

SERIAL NO.	GROUP ART UNIT	ATTACHMENT TO PAPER NUMBER
152,238	263	3

APPLICANT(S): Lau

U.S. PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE
	A	4542502	8/85	Levinson et al.	370	88	
	B	4683563	7/87	Rouse et al.	370	16	
	C	4710915	12/87	Kitahara	370	16	
	D						
	E						
	F						
	G						
	H						
	I						
	J						
	K						

FOREIGN PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	COUNTRY	NAME	CLASS	SUB-CLASS	PERTINENT SHTS. DWG	PP. SPEC.
	L								
	M								
	N								
	O								
	P								
	Q								

OTHER REFERENCES (Including Author, Title, Date, Pertinent Pages, Etc.)

R

S

T

U

EXAMINER	DATE
WELLINGTON CHIN wc	9/25/88

* A copy of this reference is not being furnished with this office action. (See Manual of Patent Examining Procedure, section 707.05 (a).)

PTO - 948
(Rev. 8-82)

GROUP 263

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

ATTACHMENT TO PAPER NUMBER 3

S.N. 152238

NOTICE OF PATENT DRAWINGS OBJECTION

Drawing Corrections and/or new drawings may only be submitted in the manner set forth in the attached letter, "Information on How to Effect Drawing Changes" PTO-1474.

A. ☑ The drawings, filed on 2-4-88, are objected to as informal for reason(s) checked below:

1. ☐ Lines Pale.
2. ☐ Paper Poor.
3. ☐ Numerals Poor.
4. ☐ Lines Rough and Blurred.
5. ☐ Shade Lines Required.
6. ☐ Figures Must be Numbered.
7. ☐ Heading Space Required.
8. ☐ Figures Must Not be Connected.
9. ☐ Criss-Cross Hatching Objectionable.
10. ☐ Double-Line Hatching Objectionable.
11. ☐ Parts in Section Must Be Hatched.
12. ☑ Solid Black Objectionable. FIG. 2
13. ☐ Figure Legends Placed Incorrectly.
14. ☐ Mounted Photographs.
15. ☐ Extraneous Matter Objectionable. [37 CFR 1.84 (1)]
16. ☐ Paper Undersized; either 8½" x 14", or 21.0 cm. x 29.7 cm. required.
17. ☐ Proper A4 Margins Required:
    ☐ TOP 2.5 cm. ☐ RIGHT 1.5 cm.
    ☐ LEFT 2.5 cm. ☐ BOTTOM 1.0 cm.
18. ☐ Other:

B. ☑ The drawings, submitted on 2-4-88, are so informal they cannot be corrected. New drawings are required. Submission of the new drawings MUST be made in accordance with the attached letter.

EXHIBIT G

IN THE UNITED STATES
PATENT AND TRADEMARK OFFICE

1-11-89
D. Little

Chi-Leung Lau
Case 1
Serial No. 152,238 Filed February 4, 1988
Group Art Unit 263
Examiner W. Chin
Title Survivable Ring Network

THE COMMISSIONER OF PATENTS AND TRADEMARKS
WASHINGTON, D. C. 20231

SIR:

In response to the Office action dated October 6, 1988 (application paper No. 3), please amend the above-identified application as follows:

IN THE SPECIFICATION

Page 5, line 1, replace "bold" with --dashed--.

IN THE CLAIMS

Please amend claims 1, 3, 4, 5, 7 and 8 as follows:

A1

1. (Amended) In a communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each node including subrate transmitters with associated multiplexers and demultiplexers with associated subrate receivers, an [the] improved node comprising

monitoring means, associated with the first ring and the second ring [rings], for evaluating the integrity of the multiplexed subrate communications on the first ring and the second ring, respectively [each of the associated

rings], and

A1

insertion means, associated with the demultiplexers and said monitoring means, for inserting an error signal on designated ones of the subrate communications in response to said monitoring means detecting a lack of integrity on the multiplexed subrate communications on the first ring or the second ring or both the first ring and the second ring [at least one of the associated rings].

3. (Amended) In the communications network of claim 1, the improved node wherein the multiplexers multiplex selected subrate communications containing said error signal into a multiplexed subrate communication for transmission onto the first ring or the second ring or both in correspondence to said detection of said error signal [the associated rings].

A2

4. (Amended) A communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each of said nodes including subrate transmitters and subrate receivers and further comprising:

monitoring means, associated with the first ring and the second ring, for evaluating the integrity of the multiplexed subrate communications on the associated first ring and the associated second ring, respectively [each of the associated rings],

means for demultiplexing the multiplexed subrate communications on the associated first ring and the associated second ring into subchannels wherein at least one of said subchannels is sent to [a] one of the corresponding receivers [receiver],

insertion means associated with said demultiplexing means to insert an error signal on each of

said subchannels in response to said monitoring means detecting a lack of integrity on the multiplexed subrate communications on [one] the associated first ring or the associated second ring or both the associated first ring and the associated second ring [of the associated rings],

selector means associated with said demultiplexing means for selecting, in response to the detection of said error signal on one of the subchannels, one of the other subchannels, and

multiplexing means for multiplexing subchannels and inserting multiplexed subrate communications onto the associated first ring and the associated second ring, respectively.

5. (Amended) A communications network having a first grouping of nodes interconnected by a first ring arrangement, a second grouping of nodes interconnected by a second ring arrangement, each ring arrangement conveying multiplexed subrate communications in a first direction from node to node and conveying multiplexed subrate communications in a second direction from node to node, and each node includes [comprises] subrate transmitters with associated multiplexers and demultiplexers with associated receivers, and wherein

each node comprises

monitoring means, associated with [its] the ring arrangement connected to said each node, for evaluating the integrity of the multiplexed subrate communications on [the] said associated ring arrangement,

insertion means, associated with its demultiplexers and its monitoring means, for inserting an error signal on designated ones of said subrate communications in response to said monitoring means detecting a lack of integrity on said multiplexed subrate communications on its said associated ring arrangement, and

selector means, associated with its demultiplexers, for selecting, in response to the detection of said error signal on a subrate communication, a subrate

communication that does not contain an error signal, and

wherein a preselected node of the first ring arrangement comprises;

A2

means, connected to the first ring arrangement and the second ring arrangement, for directing at least one subrate communication to the second ring arrangement and corresponding subrate communications from the second ring arrangement for multiplexing onto multiplexed subrate communications on the first ring arrangement.

7. (Amended) In a communications network having a plurality of nodes interconnected in a ring configuration by a first ring which conveys multiplexed subrate communications around the first ring from node to node in one direction and a second ring which conveys multiplexed subrate communications around the second ring from node to node in the other direction, each node including subrate transmitters with associated multiplexers and demultiplexers with associated receivers, an improved method associated with each node comprising the steps of

A3

evaluating the integrity of the multiplexed subrate communications on the first ring and the second ring [each of said associated rings] with monitoring means associated with both the first ring and the second ring, and

inserting an error signal on designated ones of said subrate communications in response to said monitoring means detecting a lack of integrity on said multiplexed communications on the first ring or the second ring or both the first ring and the second ring [at least one of said associated rings].

8. (Amended) The method as recited in claim 7 further comprising the step of selecting, in response to the detection of said error signal on said at least one of the subrate communications, another of the subrate communications that does not contain an error;

Remarks

Claims 1-8 are pending in this application. As a result of the instant Office action, claims 1-8 stand rejected under 35 U.S.C. 112, second paragraph. However, the Examiner did indicate that claims 1-8 "would be allowable if rewritten or amended to overcome the rejection under 35 U.S.C. 112."

With respect to particular claims, the Examiner sets forth the following reasons as the basis for the rejection.

Claim 1

(a) "the improved node" on page 8, lines 10-11, lacks antecedent basis;

(b) on page 8, line 12, it is unclear what "the rings" is referring to, as there is no clear antecedent for this terminology; and

(c) on page 8, lines 14 and 20, respectively, it is unclear what structure "the associated rings" is referring to.

The Applicant has rewritten claim 1 to overcome the Examiner's reasons for rejecting claim 1. In particular, claim 1 now recites "an improved node" thereby indicating the first appearance of this structure in the claim. In addition, claim 1 now explicitly calls for "the first ring and the second ring" instead of "rings" so as to clarify the interrelationship among the various claim elements.

Claim 3, which is dependent on claim 1, has been amended to recite that the error signal is multiplexed for transmission onto "the first ring or second ring in correspondence to said detection of said error signal".

Claim 4

(a) on page 9, lines 6-7, it is unclear what "the associated rings" are, and it is unclear as to what the rings are associated with and there is no clear antecedent for the first and second ring only.

(b) on page 9, lines 10-11, it is unclear if "a corresponding

receiver" is meant to refer to one of the subrate receivers previously recited.

The Applicant has amended claim 4 in a manner similar to claim 1 in that the reasons for rejecting claim 4 are substantially the same used to reject claim 1. Claim 4 now calls for "the first associated ring" and "the second associated ring" in place of the less explicit term "rings".

Claims 5-8 have been rejected by the Examiner "for similar reasons for those set forth above" with respect to the rejections of claims 1 and 4. Accordingly, the Applicant has amended independent claims 5 and 7 in substantially the same manner as claims 1 and 4 to overcome the Examiner's rejections and place these claims in condition for allowance. In particular, claim 5 has been amended to clarify that each node has a monitoring means associated with the ring arrangement connected to each particular node and that the means for directing is connected to both the first ring arrangement and the second ring arrangement. With respect to claim 7, this claim now calls for "evaluating the integrity ... on the first ring and the second ring with monitoring means associated with both the first ring and the second ring", thereby clarifying any ambiguity in a manner commensurate with claim 1. Also, claim 8 has been amended for clarity in a manner commensurate with claim 2.

Finally, the drawing was objected to because (i) the figures lacked descriptive labels and (ii) bold black lines were used in FIG. 2 to differentiate lines carrying error signals from lines without error signals. The Applicant proposes that the bold lines in FIG. 2 be replaced with dashed lines, as shown on the enclosed, red-inked marked FIG. 2. The specification, on page 5, line 1, has been changed to reflect this change in FIG. 2. Does the Examiner concur with this proposed change? In addition, the Applicant requires guidance with respect to the objection on the basis that the figures lack descriptive labels. The Applicant has perused each FIGURE and believes all required descriptive labels/reference numerals have been clearly